
Master of Science in Economics

# Does public investment contribute to regional convergence? An econometric approach to the Portuguese Regions (NUTS III)

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*"….From the determination thou haft tooke*
*Recoyle not. It is imbecility*
*when once a thing's begun, then back to looke…."*

Adapted from Lusíadas, Canto I

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# ABSTRACT

Dissertation Title: Does public investment contribute to regional convergence? An econometric approach to the Portuguese Regions NUTS III level (Nomenclature of Territorial Units for Statistics of EUROSTAT, the Statistical Office of the European Union).

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The main objective of this present Master dissertation is to analyze the process of convergence among Portuguese Regions at NUTS III level over 1988-2005 period and the potential contribution of regional public investment allocation to that process.

To meet this goal the regional per capita GVA average growth rate was used as well as a proxy of the public investment variable based namely on the Community Support Frameworks expenditure. $\sigma$-convergence and $\beta$-convergence neoclassic growth model hypothesis were applied in a context of a panel data analysis methodology.

The results show evidence of regional convergence, that is, faster per capita GVA growth in the poorest regions, during the global period, although Portuguese regions remain quite asymmetric in terms of that indicator. This result was not verified for all of the three sub-periods considered.

However on the main question of this thesis data did not show a significant statistical relation between public investment and per capita GVA average growth rate. The public investment allocation was not such as to privilege the reduction of asymmetries and the result was that the investment channeled to the poorest regions did not have a significant effect on the growth.

In spite the fact that Portuguese Government has been investing considerably on infra-structures programs and used public investment variable to promote economic growth, it is not possible to assure that its allocation has really contributed to reduce the asymmetries among its NUTS III regions.

# SUMÁRIO EXECUTIVO

**Título da Dissertação:** O investimento público contribui para a convergência económica regional? Uma abordagem econométrica das Regiões Portuguesas ao nível NUTS III (Nomenclatura das Unidades Territoriais para Fins Estatísticos do EUROSTAT – Gabinete de Estatísticas da União Europeia).

**Autor: Mavilde Modesto**

O principal objectivo da presente dissertação de Mestrado é analisar o processo de convergência das regiões portuguesas ao nível das NUTS III no período 1988-2005 e a contribuição da afectação ao nível regional do investimento público para esse processo.

Para a concretização deste objectivo foi usada a taxa média de crescimento do VAB *per Capita* regional bem como uma *"proxy"* da variável investimento público baseada principalmente na despesa realizada no âmbito dos Quadros Comunitários de Apoio. Utilizaram-se as hipóteses $\sigma$-convergência e $\beta$-convergência do modelo de crescimento neoclássico no contexto de uma metodologia de análise de dados em painel.

Os resultados mostram evidências de convergência regional durante o período global isto é, mais rápido crescimento do VAB *per Capita* nas regiões mais pobres, embora as regiões portuguesas permanecem bastante assimétricas em termos deste indicador. Este resultado não se verificou para os três subperíodos considerados.

No entanto, sobre a principal questão desta tese, a informação não mostra uma relação estatística significativa entre investimento público e a taxa média de crescimento do VAB *per Capita*. A afectação do investimento público não foi de modo a privilegiar a redução das assimetrias e o resultado foi que o investimento, abaixo da média, feito nas regiões mais pobres, não teve efeito significativo no crescimento.

Apesar do Governo Português ter vindo a investir consideravelmente em programas de infraestruturas e usado a variável investimento público para promover o crescimento económico, não é possível assegurar que a sua afectação tenha realmente contribuído para reduzir as assimetrias entre as regiões NUTS III.

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# 1. INTRODUCTION

This study seeks to explore the empirical relationship between regional public investment breakdown, per capita income growth and the regional convergence achievement of Portuguese regions at NUTS III (Nomenclature of Territorial Units for Statistics) level, during the period 1988 - 2005.

To analyze the convergence of Portuguese Regions we are going to use the indicator GVA per capita and to the analysis of public investment contribution we will use a proxy variable based namely on the expenditure realized under Community Support Frameworks (CSF's) which Portugal have been benefiting whether as a member of the European Union or as one of the group of cohesion countries. This proxy results from a thorough clearance and methodological treatment of CSF data and municipalities' capital expenditures, made by the author.

Based on the Solow's model and Barro and Sala-i-Martin contribution it is expected that poor regions grow faster than the rich ones, converging to the same level, at the long run. There are not unanimous views in economic theory about this subject. The strict convergence analysis based on neoclassic growth model points out that poor regions growth faster than the richest ones catching up the level of the latter, while endogenous growth model highlights the reduction in costs in those regions and subsequent agglomeration effects. Moreover, empirical studies' results also go in both directions (Aschauer (1989a, 1989b) and Garcia-Milà, et al., (1996)). Then we are going to understand what happened across Portuguese regions using absolute and conditional $\beta$-convergence concepts and bearing in mind that Portugal received considerable amount of European transfers to support public investment projects, to reduce regional imbalances and promote its development. Therefore, a relevant question is to explore if this policy has reached its goal or rather accentuated regional disparities.

Regarding the public investment contribution for the growth and convergence process we present a brief characterization of the relevance of public investment in Portugal as well as its regional allocation. We explain the construction of the database used in the

analysis. Following Rodriguez-Pose, et al., (2012) we look for understanding if there is a territorial dependence on public investment allocation and subsequent externalities on regional growth.

A potential positive effect of public investment on regional convergence assumes that it is priority driven to the less developed regions. Following Aschauers' views there is a positive link between public and private investment leading to the growth. The public investment is then a crucial condition to the growth process. On the other hand, in economic theory there is no unanimity about this link and some empirical studies establish that there is no clear relation between public investment and economic growth (Garcia-Milà, et al., 1996). Several factors may distort the expected result: the allocation itself and its adequacy to the specific region, the type of investment, the regional policy guided by political or even economic criteria favoring most developed regions taking advantages of scale or specificities.

In our work we follow partially (Rodriguez-Pose, et al., 2012) that in a recent work on the Greek regions have just developed an analysis of the impact of public investment on growth and regional convergence at the same NUTS III level.

To explore these questions, in our analysis, a panel data set and econometrics techniques will be used.

Firstly we will look for the existence of $\beta$-convergence (absolute and conditional) among Portuguese Regions at NUTS III level, in line with the contributions of Barro e Sala-i-Martin. Secondly we will explore the potential contribution of public investment on that process. Also we will look for understanding whether there is a spillover effect from the public investment in neighboring regions on a specific region. Following Rodriguez-Pose, et al., (2012) we will use a spatial binary matrix W which allows for taking account of that possible spatial dependence.

From the results we will take some answers to our main questions as well as some policy implications regarding public investment policy.

To the best of our knowledge, our work is the first one that explores the relationship

between the Portuguese regional allocation of public investment and the regional convergence at NUTS III' level, based on a panel data analysis methodology and using a database of public investment namely collected from the sources who manage CSF's as it will be explained later on. Our contribution yet adds the search of spatial dependence on public investment allocation.

At least, to our knowledge, there are very few studies on the convergence of the Portuguese regions and even fewer relating it to the contribution of public investment. Our study adds this perspective and applies it to a more desegregated territorial level (NUT III).

Our results differ from those obtained by Rodriguez-Pose, et al., (2012) in their study for Greek regions whereby they conclude for a positive impact of public investment per capita on regional growth but reject the hypothesis of conditional $\beta$-convergence for the period 1978-2007.

After this introduction, the motivation and framework of this study will be presented in section 2, where some concepts and theoretical foundation of convergence analysis will be exposed as well as its relation with public investment expenditure. This section yet contains a literature review on public investment, economic growth and convergence in general and, in particular some concerning Portuguese reality on this subject. Section 3 briefly explicit the relevance of public investment in terms of data presentation, its frame decision, regional allocation and evolution along the period 1988-2005 in Portugal and results' analysis on $\sigma$-convergence. Under section 4, the econometric analysis for absolute and conditional$\beta$-convergence is first specified, followed by the explanation of the methodology. Section 5 present and analyze the empirical results. Finally, section 6 concludes, describes limitations and indicates possible implications.

# 2. MOTIVATION AND FRAMEWORK

## 2.1. A Preliminary Approach

In several western economies, regional policies made strong efforts on the provision of such level of infrastructures and other public investment projects that guarantee the development of economic activity. This strategy is based on the recognition of public investment as a promoting mechanism of greater economic growth underlying a direct relationship between public capital and per capita income growth rate, potentially allowing for regional convergence achievement.

At the European Community level, country and regional convergence has been addressed by Community Support Frameworks, namely through the Structural Fund - European Regional Development Fund (ERDF) - and the Cohesion Fund[1], considering then the key role of the investment as a tool to the economic growth, namely the public investment on infra-structures and education. There is then the thinking that public investment is a way to the economic development and to the reduction of regional disparities. This is reflected in the consideration of EU Cohesion Countries Group encompassing Portugal, Greece, Ireland and Spain, whose levels of income per head were behind those of European average.

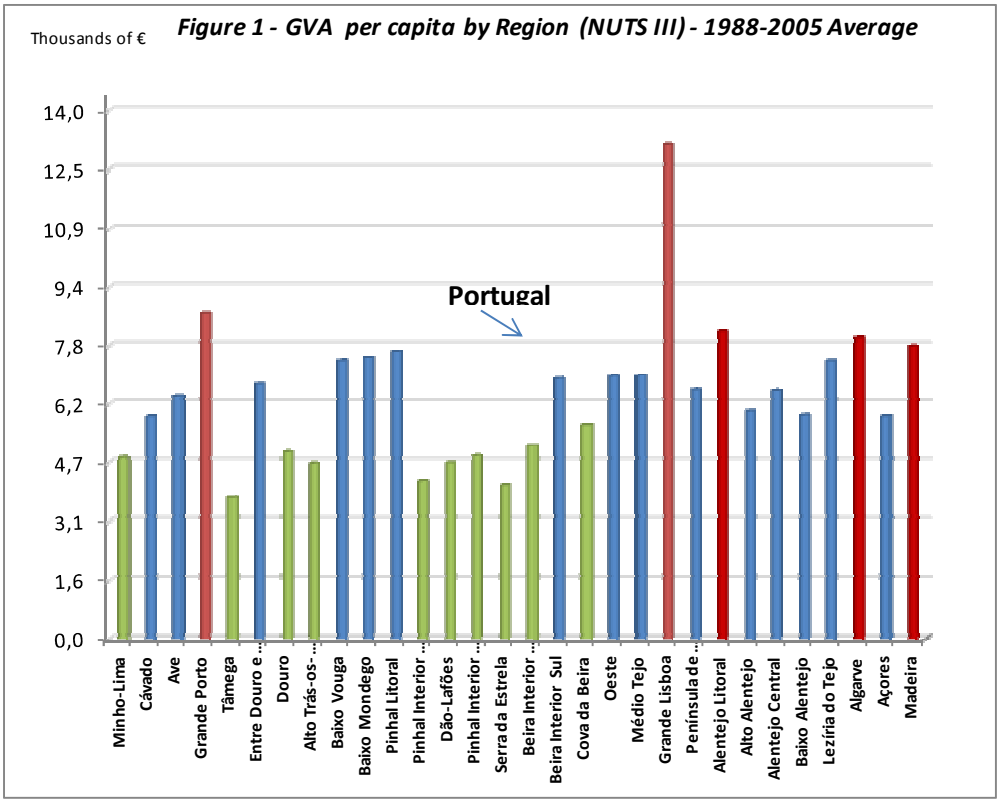
Portugal had become a Membership of the European Community in 1986 and participates in the European Monetary Union - (EMU) since its beginning in1999. Since 1986 Portugal benefited from a pre-adhesion aid followed by a first Community Support Framework (1989-1993), a second one (1994-1999) and a third one (2000-2006). Nowadays, Portugal is still benefiting from National Strategic Reference Framework (2007-2013). These programs envisage promoting the development at a national level and reducing regional asymmetries namely through the creation of infra-structures, even if each one of the three CSF's have had different patterns, goals and priorities.

[1] Cohesion Fund, created in 1993, provides support to environment and transport projects

At national level, despite Portugal is nowadays undertaken with "Memoradum[2]" and faces budget constraints implying tough reductions on public expenses in general and on public investment in particular, public policies have been considering this latter as a key to the economic growth, real regional convergence and reduction of asymmetries.

Meanwhile, at NUTS III regional level, Portuguese regions are quite asymmetric in what regards their per capita GVA level and regional imbalances pertains. Actually, along the period 1988-2005, 25 of the 30 NUTSIII regions present a per capita GVA ratio below the one at national level and ten of them do not reach 75% of that (Figure 1).

There is significant amplitude when we compare GVA per capita between the richest (Grande Lisboa) and the poorest region (Tâmega). Grande Lisboa and Grande Porto, the first and the second richest regions, overcome the national value in about 68% and 10% respectively.




[2] Memorandum of Understanding on Specific Economic Policy Conditionality – The Program negotiated by Portuguese authorities, the European Commission in liaison with the ECB and the IMF, in May 2011.

This situation motivates us, to study whether any convergence had occurred between Portuguese regions, as well as understanding if public investment had contributed to that process.

In fact, regional public investment allocation and regional economic growth confront policy makers with a trade-off between efficient allocation of resources and equity. Fostering the investment in less developed regions, aiming their convergence to the high developed ones, may means sacrificing economic growth at regional and national level. The returns on public investment can be higher, due to complementarities, on average in more developed regions. That means that allocating public investment in favor of less developed regions may involve an efficiency cost to the country as a whole due that allocation in regions with lowers productivities considering the benefits and the opportunity and financing costs.

## 2.2. Convergence Analysis and Theoretical Foundation

### 2.2.1. Concepts – State of the Art

Concepts like cohesion, convergence or disparity are used as wide concepts in regional and convergence analysis. Hence, some clarification is need about that.

In the context of the European Union, according the article 158.º of the European Union Treaty, cohesion is viewed as a development question, "In particular, the Community shall aim at reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions…". Thus, "cohesion is a measure of welfare that embraces inequalities, whether in income terms, living standards, employment or of environmental conditions. It has to be seen in terms of opportunities as well as outcomes" (Ardy et al., 2002a).

"Cohesion …has all to do with investment – modernizing the European economy, promoting growth and sustainability and producing beneficial spill-over effects. It is about investing in innovation, human capital and modern infrastructure"[3].

From the sentences above we can say that cohesion is used as a synonymous of convergence, but also as the forces (policies) which could lead to that convergence.

By regional economic cohesion one means the aim of promoting convergence through faster GDP growth in the poorest regions[4]. Regional allocation of public investment may contribute to that goal through a direct or indirect impact on laggard regions.

The Convergence concept is based on "real variables" such as per capita product or productivity, despite it has got different connotations in the literature (Alasia, 2002). Two concepts of convergence were first introduced by Sala-i-Martin (1990): σ-convergence (sigma-convergence) and β-convergence (beta-convergence).

The first one, σ-convergence (sigma-convergence), is a type of convergence that refers to the dispersion of the indicator under study. There is σ-convergence when the data dispersion decreases along the time. The latter can be measured by the coefficient of variation[5].

A second type of convergence is β-convergence (beta-convergence) that happens when the per capita product growth rate of different regions/zones/countries tend to be higher for poor countries at the long term equilibrium (equation 1). This would be the prediction of the Solow model for countries with identical fundamentals. It is verified empirically exactly on these conditions.

[3] Danuta Hübner - Member of the Commission responsible for Regional Policy - Regional policy and the Lisbon agenda – Challenges and Opportunities – Speech/05/70 at London School of Economics - London, 3. February 2005.

[4] First Cohesion Report (European Commission, 1996)

[5] $\frac{\sqrt{\frac{1}{N}*\sum_{i=1}^{N}(y_i-\bar{y})^2}}{\bar{y}}$

Another possibility of measuring σ-convergence could be through the quotient of variable standard deviation at final (t) and initial period (0)

Following Sala-i-Martin (1990), Barro and Sala-i-Martin (1991), Mankiw et al. (1992), we can also distinguish conditional from absolute convergence, that is, the concept of β-convergence is itself viewed with a double meaning: the absolute (or unconditional) β-convergence and the conditional β-convergence.

When analyzing absolute-unconditional β-convergence it's assumed that all the economies converge to the same, "single and global equilibrium of steady-state" and that there is homogeneity among their structural characteristics. As a consequence, poor countries will grow faster and over time, real convergence of per capita real output will approach each other.

By contrast, conditional β-convergence considers the economies' heterogeneity and the relevance of others elements beyond the differences in product per capita, such as education background, saving and investment rate, among others elements that condition the process for the stationary level of per capita output.

Thus, even if each economy tends to its own equilibrium's steady-state (Barro R.J. and Sala-i-Martin, 1995), the growth rate of different countries can be not negatively correlated with the level of GDP per capita. However it is conditional when after controlling for differences across countries there is a partial negative correlation between level and growth rates.

Conditional β-convergence is, in general, tested through an econometric model, in which, specific variables that differentiate between each other region, are isolated and controlled (maintained constant), that is, different regional economic structures are considered through a vector of specific variables ($x_i$) that maintain constant the stationary state of the region $i$ /economy.

$$\frac{1}{T} ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \propto + \beta ln(y_{i,0}) + \gamma x_i + \varepsilon_i \qquad \varepsilon_i \sim i.i.d(0, \sigma_\varepsilon^2) \qquad (1)$$

That vector $x_i$ may encompasses, among others variables, the stock of capital, public consumption, public investment, demographic information, health and education or indicators of political stability (Barro R.J. and Sala-i-Martin, 1995).

In equation (1), $ln(y_{i,0})$ is the initial value of the variable under analysis and $\frac{1}{T} ln\left(\frac{y_{i,T}}{y_{i,0}}\right)$ is its average growth rate along T periods. The coefficients $\propto$ and $\beta$ are respectively a constant and the coefficient of convergence.

From that equation, when $\gamma = 0$, then we have the usual expression for testing the absolute convergence.

There will be β-convergence (absolute or conditional) when β is negative and statistically significant, meaning that the average growth rate per capita product, between 0 and t periods, is negatively correlated with the initial level of product per capita.

Whereas estimating equation 1, for conditional β-convergence, we can separate two effects on growth. Just the β effect of the initial per capita product capturing the convergence process and, another one, concerning the effect on growth of the explanatory variables included in $x_i$ which allows to evaluate its contribution to the growth process. Referring to the first one, there is a negative relation between the per capita growth rate and the distance at what its level is from its steady-state's equilibrium. Hence, poor regions may not growing faster than the rich ones if the latter are further away from their steady-state' equilibrium. Again, this is the simple notion of conditional convergence[6].

Two others related concepts are the one of "convergence speed"[7], which measures the speed at what the economy converge towards the steady state and the other one of "half-life" to calculate the time required for reaching half of the lag separating from that equilibrium[8]. The speed of convergence is greater the higher is β.

[6] Another concept used in the literature is the one of convergence's club that we do not develop in this study. It refers to the identification of some regions with similar initial conditions and structural characteristics – the club – that, at a long term, tend to converge at same path, generating regional polarization around these clubs and maintaining the economic disparities (Jean-Pierre P.La, 1999).

[7] Calculated through the following expression: $\lambda = -\frac{\ln(1+\beta)}{T}$ where T stands for the number of periods

[8] Half-life: $\tau = -\frac{\ln(2)}{\beta}$

To this analysis yet it is to mention the importance of spatial dependence that refers to the organization of the economic activity in a territorial space, where some processes may influence across neighbouring territory or, vice versa. Labor force and capital mobility, transportation or transaction costs or trade flows are examples of factors resulting in spatial dependency. It implies that geographic units are spatially correlated and modeling this dependence.

Following Anselin (2000), "spatial autocorrelation can be defined as the coincidence of value and location similarity. Therefore, there is positive spatial autocorrelation when high or low values of a random variable tend to cluster in space and, there is negative spatial autocorrelation when geographical areas tend to be surrounded by neighbors with very dissimilar values" (Baumont, et al., 2000).

### 2.2.2. The Approach of the Convergence Analysis – The Debate

The analysis of convergence's concepts is related to the neoclassic growth models hypothesis. According to these, regions with lower income levels tend to register a greater rate of growth and so, in a long term, catching up the richest ones. The neoclassical perspective convergence is due to the presence of diminishing returns to the capital in the process of capital accumulation. As the most developed regions use productive factors more intensively than the less developed ones, they tend to growth at a slower path than the latter (Solow, 1956; Swan, 1956). Therefore, a similar investment rate would imply higher growth in laggard regions than in the richest ones. On the other side, models of endogenous growth emphasizes a different paradigm, assuming constant or increasing returns as a result of agglomeration externalities and decreasing costs which attract capital and labor flows to the more developed countries and subsequent growth. The identification of this difference is important since each has different political implications.

As stated before, the neoclassical convergence process achieves the reduction of initial income differential convergence through diminishing returns to the capital, correcting the disparity between regions, even without a public intervention. Public policy would

have a positive effect on growth during the transition to the steady-state when it improves the steady state level of output per capita. Endogenous growth theory focuses on the existence of increasing returns to scale that might generate greater regional income disparities, then, requiring public policies for faster growth of poor regions.

Measuring the convergence hypothesis has been viewed as a test between these two different approaches on economic growth being at the base of an important debate. However Quah (1996b) warns to the concept of β-convergence. It is "misleading" to understand convergence. "His critique is both methodological - studying an average or representative economy gives little insight into the empirical behavior of the entire cross-section - as well as technical - the "law of convergence" may be partially explained by a statistical artifact, the unit roots in the time series data. On the other hand, Sala-i-Martin (1996) argues that β-convergence is, together with other convergence concepts, a relevant one; he also points out that although statistical problems are theoretically possible, they are unlikely to be the cause of the observed convergence" (Alasia, 2002).

Ultimately, empirical studies, concerning interregional inequalities, have been assuming increasing importance in the economic literature to fundament the implementation of public policies that promote the development of backward regions, even though presenting controversial results.

In the context of economic integration like the one concerning Portugal as a member of European Union, one question to be risen is how the new elements of integration like those of free flows of goods and factors impact on the product per capita member states or regions' convergence. According to the hypothesis of the neoclassic growth models, over time, income should growth faster in initially low-income regions. Meanwhile, the economic geography perspective has been considering that not only initial levels of per capita product matters, but also, their size and location to the core territories, what may divert from that view. The activity agglomeration in more economic advanced regions may generate increasing returns to scale and decreasing costs, leading to a polarization activity in those regions, rather than convergence with

the laggard ones[9]. In fact the spatial dynamic may play an important role in the economic growth as well as institutional and politics factors.

The goal of this study is rather to analyze the per capita convergence hypothesis between Portuguese NUT III regions at 1988-2005 span as well as the understanding of the contribution of public investment to the regional convergence.

### 2.2.3. Convergence and Public Investment

We just have described that β conditional convergence can be studied after controlling for other variable that affect the growth rate. Which variables should be used to signal significant effect on growth? The economic theory, suggests that public investment is one of the main instruments that affect growth. If the distribution of public investment across regions is such that is biased to less developed regions then we can say that achieving regional convergence is an objective of policy. In fact, economic disparities, public investment and convergence between regions and countries are of interest of many academics in order to assess how they do interact. The point is to understand if economies (regions) tend to converge towards the same per capita level and what's the contribution of investment to that.

Although private capital accumulation is, in general, considered as the engine for economic growth, common thinking suggests that public investment always provide the framework to that goal, even if some state that public investment may crowds out the private one. It is noteworthy that already in the fifties, Galbraith warned about the perils of neglecting the public infrastructure (Galbraith, 1958). As we have seen, for example using equation (1), the neo-classic economic model provides theoretical framework to access the impact of public policy, by analyzing the sign and the significance of $\gamma$ when $x_i$ is public investment. The relation between per capita product and physical capital through its dynamic variation can be analyzed since the first works in this area. See for example (Solow, 1956), (Swan, 1956), Cass and Koopmans (1965) and (Barro, 1990). Meanwhile, Aschauer has contributed to a great deal of interest

[9] An Agenda For a Growing Europe – Making the EU Economic System Deliver (2003)

about the effect of public capital spending on private productivity and output (Aschauer, 1989a).

Thus, this dissertation resorts mainly to two areas of economic theory: the issue of regional convergence and the effect of public investment on economic growth and therefore on regional convergence.

## 2.3. Literature Review

### 2.3.1. Public Investment, Economic Growth and Convergence

There is a wide range of literature analyzing the positive implications of public spending, in particular of public investment, on economic growth (For a synthesis of extensive literature see (Pereira, et al., 2004)).

Following Aschauer, "on neoclassical grounds, expansions of public investment spending is argued to induce an increase in the rate of return to private capital and, thereby, to stimulate private investment" (Aschauer, 1987). The early Aschauer' study using annual United States data ( (Aschauer, 1989a), (Aschauer, 1989b)) evaluated the effects of public capital on private product and revealed a strong positive relation between these two variables. Aschauer (1989) found an output elasticity of public capital of about 0.39 even higher than the one of private investment. Earlier studies already had presented positive estimates of that elasticity (Eberts, 1986).

Therefore, Aschauer finds that "significant weight should be attributed to public investment decisions - specifically, additions to the stock of nonmilitary structures such as highways, streets, water systems, and sewers - when assessing the role the government plays in the course of economic growth and productivity improvement" (Aschauer, 1989a). On the other hand, other researchers find that "many public policies contain disincentives for growth because they reduce the rewards to accumulation of a comprehensive concept of capital encompassing human as well as physical capital" (Schultz, 1981) (King, et al., 1990).

Some studies followed Aschauer' views – his own work Aschauer (1990, 1993), Munnell and Cook (1990) and Holtz-Eakin (1992) among others. However, some researchers have disputed Aschauer' s results namely standing that the impact of public investment could become negligible or even negative (Aaron, 1990), (Hulten, et al., 1991) (Gramlich, 1994), (Holtz-Eakin, et al., 1994), (Evans, et al., 1994) (Garcia-Milà, et al., 1996) .

The Aschauer' approach to evaluate the effects of government spending, based on the aggregate production function, also was confronted with alternatives ways like cost function, cross country and vector autoregressive models. Another objection to his approach relates to the causality of public investment to the economic growth. Public investment may be higher when there is fast growth, rather than playing a causal role of that. Thus, the criticism to the Aschauer' work concerns namely the methodological approach (the misspecification or the data non-stationarity), the magnitude of the effects he found and the direction of a clear causation from output to public investment or the reverse (Munnell, 1992).

Although nowadays there is a consensus that public capital stimulates economic growth, some researchers emphasize the lack of a clear positive link between public capital and private output and underlines that the results are not unanimous, varying significantly with the empirical approach, the country and the period considered. Moreover, when a positive effect is pointed out by recent studies they are significantly lower than those showed by Aschauer and first studies (Sturm, 1998). (For a more recent survey of the theoretical and empirical literature, see Romp and de Haan, 2005). (Romp, et al., 2005).

A particular important question is to understand if the relation between public investment and output presented to the national level also holds at regional level. Aschauer' findings were followed by a large number of studies about the impact of public investment at regional level which stimulated the research on this subject, in particular relating its effects on convergence. Holtz-Eakin (1994) pointed out the fact that public investment effects estimates are identical, both at aggregated and regional level. Great part of these studies concern the United States.

Meanwhile, much of the more recent empirical work about the effect of public investment and convergence relates to European Union (EU) countries (regions) where the assumption to invest the European Structural Funds and to deep the integration process aims favouring less developed countries to increase their per capita income and to reduce disparities among countries /regions (Cappelen, et al., 2003).

Again, there isn't clear evidence about a robust link between public investment and per capita product convergence. The study "The impact of public investment on the Portuguese economy" from Pereira and Andraz (2004) is to mention. It suggests that the public investment has contributed to the concentration of economic activity in the richest regions - Lisboa Vale do Tejo – rather than reducing regional asymmetries along the period they have analyzed (1980-1998). Similar conclusions were drawn by (Lago-Peñas, et al., 2005) for Spanish regions, who found the evidence of economic activity concentration in the richest regions over 1985-2003 period, although a redistribution of regional public investment allocation. In the already mentioned study for Greek regions along 1978-2007 period, (Rodriguez-Pose, et al., 2012) have concluded for a positive and significant impact of total public infrastructure expenditure on regional growth, but they did not find a clear contribution of public investment reducing the development gap across Greek regions. Analyzing regional convergence and public spending for Italian regions, (Daniele, 2009) concluded that absolute and conditional convergence analysis during the period 1980-2007 showed a weak process of convergence in per capita GDP.

For the European Union as a whole, despite the main objective of reducing economic and social disparities between its members, the evidence on the convergence between them is mixed. Some studies highlight the countries' convergence to the European income average but divergence inside the countries themselves. See for example (Dall'erba, et al., 2004) and (Fayolle, et al., 2000). Among those with a negative perspective of transfers to the lagged European countries aiming the convergence process is for example (Boldrin, et al., 2002) (Boldrin, et al., 2003), (Rodríguez-Pose, et al., 2003) or (Gallo, et al., 2007). In an opposite sense stand (Eijffinger, et al., 2005),

(Cappelen, et al., 2003), (Mohl, et al., 2008). The most part of these studies were oriented to the evaluation of the European regional policy.

Several factors may explain divergent conclusions: not taking into account regional heterogeneity, interaction between agglomeration of economic activities and regional growth processes and subsequent regional spillovers effects of public capital, or even political and institutional factors, for example.

In fact, geographical space has acquired an outstanding role and more recent research emphasizes the importance of factors' location and mobility across regions as well as their interactions. Thus, they integrate externalities and spatial characteristics within the regional growth and convergence analysis.

### 2.3.2. Public Investment and Convergence for Portugal

In what concerns Portugal, it is worth mentioning some studies like those of Ligthart (2000), Pereira and Andraz (2004), Pina and St. Aubyn (2004) which suggest a positive relation between public investment and growth. These studies follow a similar methodological approach based on a vector autoregressive model. Only the second study drives the analysis at a regional level.

Ligthart (2000), employing annual data for the country as a whole over the period 1965-1995, conducted an empirical analysis on the output effects of public capital in Portuguese economy. Her results show that public capital is an important determinant of output growth and that there is a "substantial growth payoff from public investment".

Pereira and Andraz' study (2004) - "The Impact of Public Investment on Portuguese Economy"- presents public investment as a driving force to the national economic growth. They consider public and private investment, product, and employment data from seven NUTSII[10] Portuguese regions, over 1980-1998. Their analysis is based on an

[10] Norte, Centro, Lisboa e Vale do Tejo, Alentejo and Algarve

ARV model (Auto Regressive Vector). Instead of a classical production function they consider that the ARV approach allows the consideration of dynamics effects between all variables involved in public investment analysis. On the most part of regions considered, their results point positive effects of public investment over almost all variables. They also show the importance of "spillover effects" rather than direct effects on each region. Meanwhile, they do not analyze if there have had economic convergence between Portuguese regions although noticing that public investment tends to go to major regions contributing to the economic activity concentration in those regions, particularly in Lisbon and Tagus Vale.

Pina and St. Aubyn (2004) also compute the rate of return for public investment to Portugal and conclude for a positive effect on the private investment. Using an ARV model they compare the return of public investment, with that of physical private and human capital investment over 1960-2001 and found that the first one has the highest rate of return (Pina, et al., 2004). Again the question of convergence is not raised in this study.

# 3. THE RELEVANCE OF PUBLIC INVESTMENT IN PORTUGAL: INSTITUTIONAL PRESENTATION, DATA CONSTRUCTION AND ANALYSIS

It is considered that the Investment is one of the macroeconomics variables most responsible for the economic development. Private investment is decided by private economic agents according to their objectives, market dimension and characteristics, demand, factor costs and regulatory and economic environment, among others. By contrast, public investment is decided by the Government and largely determined by the macroeconomic environment and electoral scrutiny in a given normative and institutional framework.

### 3.1. Frame Decision of Public Investment in Portugal

Nowadays, the Portuguese Constitution[11] stipulates as a fundamental task of The State "to promote the harmonious development of the entire national territory, taking into account the peripheral character of the Azores and Madeira"[12] and "to promote economic and social cohesion of the entire national territory, guiding the development towards a balanced growth of all sectors and regions and progressively eliminating the economic and social differences between the city and the countryside and between the coast and the interior"[13].

Concerning the Plans, the Portuguese Constitution keeps establishing that "the plans of social and economic development are intended to promote growth economic, harmonious and integrated development of sectors and regions, the fair individual and regional distribution of the national product, the coordination of economic policy with the social, educational and cultural policies, defense of rural life, the preservation of the ecological balance, environmental protection and quality of life of the Portuguese people"[14]. "National plans are drawn up in accordance with the laws of the Major Planning Options and may include specific programs of territorial and sectors scope. The execution of national plans is regionally and sectorally decentralized"[15].

Since the fifties till the beginning of the eighties, public investment' orientation in Portugal was just reflected in "Developments Plans (Planos de Fomento)[16] " that had references to the investment programs from the Central Administration and Public Enterprises. Over the second half of seventies there was a program concerning the Public Administration Investment (PIAP)[17] in social equipment and basic infra-structures, and another one related to the investment of the State Business Sector

[11] Constitutional Law n.º 1/2005, August 12th, 7.ª Constitutional Revision

[12] Article 9.º.g of Portuguese Constitution – Fundamental Tasks of the State

[13] Priority Tasks of the State - Article 81. º- d of Portuguese Constitution

[14] Objectives of plans - Article 90.º of Portuguese Constitution

[15] Elaboration and Execution of Plans - Adapted from Article 91.º of Portuguese Constitution

[16] Development Plan (1953-58), II Development Plan (1959-64), Interim Plan (1965-66), III Development Plan (1967-73) and IV Development Plan (1967-74) which lasted just one year

[17] PIAP-77, Decree-Law n.º 951/76, of 31st of December, PIAP-78 and PIAP-79

(PISEE). In 1978, there was an enlargement in the program content that includes not only investment expenditures but also development expenditures by Public Administration (PIDDAP). In 1979 was prepared the Development Expenditures and Investment of Central Administration (PIDDAC). The Annual National Budget encompassed this Program in Map XI[18] containing not only public investment projects but the expenses to the development of the country financed by Central Administration. PIDDAC was just the main instrument setting public investment promoted by the State and its autonomous funds and services. Meanwhile, PIDDAC did not manage to collect together all financing sources and included namely the investment projects registered in Chapter 50.º of State Budget, being than a limited tool to analyze the amount of public investment realized by the country. Moreover, PIDDAC did not consider the projects location and only in 2005, proceeded to its regional distribution. It worth to say that PIDDAC's scope was greatly improved broadening and deepening its content.

Although some references to the correction of regional unbalances were mentioned in such programs, the allocation of public investment in Portugal was decided at central Government level, predominantly with a national scope and the regional perspective being almost inexistent. Remember that administrative regions creation in mainland Portugal was just rejected by national referendum in 1998.

Nevertheless, from the Portugal's accession to the European Community on, a regional cohesion policy began being reflected in Regional Development Program (Programa de Desenvolvimento Regional - PDR) that Portugal had to prepare in the context of each of the Community Support Framework. This was a meaning change in line with the European Cohesion Policy translated to the national level through two main instruments, the Structural Funds and Cohesion Fund. Hence, the organization of the Support Community Framework to Portugal favored the implementation of a regional development policy[19].

[18] Recalled Map XV

[19] It's worth mentioning the role played by Regional Coordination Commissions in the co-ordination at different levels (national, regional and municipalities)

In fact, Regional Development Program – RDP 89/93 that underlies the first CSF defines as main objectives reducing the unevenness of development of the Portuguese economy to the EU average and correcting internal regional imbalances. In this context the first Community Support Framework encompasses one priority axe dedicated to the regional development beside operational programs. The regions could also benefit from Development Integrated Operations of communitarian initiative aiming to support regions with specific structural difficulties and others sub-regional programs covering projects in the domain of accessibilities, sanitation conditions, supporting equipment to the productive activity, tourism, spatial planning and environment.

Regional Development Program – RDP 94/99 maintained the same objectives as the previous one, even quantifying the degree of regional disparities reduction. One of the second CSF' four axes, was devoted to strength the regional economic basis. In addition to a national program searching regional and local development it encompasses others programs corresponding to five NUTS II regions of the continent and two programs for the autonomous regions of the Azores and Madeira. This CSF integrated also the Cohesion Fund created in 1994 that is applicable to the regions whose product per capita was below 90% of the communitarian average[20].

Regional Development Program – RDP 2000/06, following the "Sustainable Social and Economic Development Plan" focused on the relevance of the investment to minimize the negative environment impact of the development and establishes three intervention areas - human potential, productive activities and the territorial enhancement.

Nowadays the fourth CSF is designated in a different way as National Strategic Reference Framework – NSRF 2007/13 and concentrates its intervention on priorities objectives such as convergence, employment and regional competitiveness and European territorial cooperation.

According this short explanation one could conclude that the main goals guiding the regional allocation of public investment have been assuming a regional cohesion policy

[20] Portugal, Spain, Ireland and Greece

and asymmetries reduction principles. However, it seems that there was not a well defined criteria determining whether public investment should go to the most developed regions, considering their higher efficiency, or to those less developed, in order to foster convergence and equity.

In addition to this failure of transparency in terms of objectives, the regional allocation of public investment is partly based on an economic criteria but it is normal to reflect the political party of forces in power, given its ability to influence the electoral vote. On the other hand some business lobbies may condition the government about the location of large investments projects.

In summary, it is not clear what was the main driving force concerning the allocation of public investment across regions in Portugal for the period under study.

### 3.2. The Data

At least to our knowledge, Portugal doesn't own a regional detailed database about public investment to a large period, allowing an econometric analysis. The National Statistics Institute (INE) provides information about Public Gross Fixed Capital Formation at regional NUTS III level for a short period of time.

For this analysis, the problem was overcome using a proxy of Public Gross Fixed Capital Formation – "the public investment expenditure" realized mainly through the CSF´s. The dynamic of public investment had been hardly related with public investment projects promoted through the Community Support Frameworks that have been benefitting Portugal since its adhesion to the European Community and even before. CSF's embody the most part of public investment decisions and imply a great dynamism on public investment projects which require important national contributions and therefore limited scope have been left for other public investment projects. Then, the data set used in this study for public investment was namely collected from different official entities[21] dealing with the execution of CSF's.

[21] The collection of Public Investment Data benefitted from having worked with former DPP – Departamento de Prospectiva e Planeamento – Prospective and Planning Department (Ministry of Environment, Spatial Planning and

Given the mentioned lack of data, the public investment' concept used in the present work is then, a wide one, and, it does not correspond to that defined in national accounts[22]. The investment expenditure reported by all bodies operating with the CSF' execution and municipalities has allowed its desegregation at NUT III regional level for the period 1988-2005 (eighteen years). Unfortunately, it wasn't possible detail the information by type of investment.

It includes public investment spending monitored by Central Public Administration in the scope of the Community Structural Frameworks and the non co-financed investment of Local Administration (the municipalities). The main resources financing these public investment projects are the National Budget and European Structural Funds, particularly the European Regional Development Fund - ERDF[23] (1988-2005), the European Agricultural Guidance and Guarantee Fund-EAGGF (1988-2005)[24] and Cohesion Fund I and II[25] (1993-2005). The expenditure realized under ERDF represents the major parcel of public investment expenditure (52.7%, 46% and 72%, respectively in the first, second and third period).

Thus, the public investment expenditure panel data consists of 30 NUTS III[26] Portuguese Regions over the period 1988-2005. All the series were made compatible referring to the same year base and adjusted to constant prices at 1995 to evaluate

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Regional Development) where I was given the opportunity to establish institutional contacts for this purpose, namely with DGDR - General Directorate of Regional Development and several different CSF's management units.

[22] In System of National Accounts (SNA) it embraces the Gross fixed capita formation of Public Administration - "Gross fixed capital formation (or gross fixed investment) (1.51)" - The activity of gross fixed capital formation is restricted to institutional units in their capacity as producers, being defined as the value of their acquisitions less disposals of fixed assets. Fixed assets are produced assets (such as machinery, equipment, buildings or other structures) that are used repeatedly or continuously in production over several accounting periods (more than one year)(1.52).

[23] It supports basic infrastructure in transport, communications, energy, environment and urban renewal; social infrastructure in education, social integration, health and the arts; modernisation of economic activity through infrastructure and incentive systems to the business sector, particularly small-and medium-sized enterprises and scientific and technological research and development action.

[24] Part Guidance - This Fund supports reconversion and adaptation of agricultural structures and the development of rural areas.

[25] The Fund supports projects which have a significant impact on the environment and transport/Trans-European Networks.

[26] Regional Data was rearranged according NUTS III Classification Revision of 2003 – Regulation (EC) n.º 1059/2003 of the European Parliament and the Council of 26 May 2003. See Map of NUTS III Portuguese Regions in annex.

the contribution of the public investment to the economic regional growth and convergence process. For the purpose of the analysis three periods were considered: 1988-1995, 1996-2000 and 2001-2005. These periods does not coincide exactly with those of CSF's but slide lightly. Although there is a delimited beginning and end for each CSF, their temporarily allocation is not precise, once effective expenditure can occur later on. Moreover, one does not intend evaluate the effects of each CSF's but consider these funds as a main portion of public investment expenditure.

The process to get this set of information and the construction of this database was quite time consuming and implied a great effort along to several sources of information and assuring its systematization and harmonization. Three institutions were the main sources of information: the General Directorate of Regional Development – DGDR, which made available the original information related with the European Regional Development Fund and Cohesion Fund I and II, the Fisheries and Agriculture Financing Institute - IFAP which provided information concerning European Agricultural Guidance and Guarantee Fund and the General Directorate of Local Administration (DGAL) making available the capital expenditure of municipalities.
Each piece of information had different formats and level of disaggregation. For instance, from DGDR we have got the yearly expenditure execution by CSF's for ERDF, although each of them had a different structure and specificities (detailed by measure, by sectors of application, for example). Further, the structure of the third CSF encompassing regional operational program beside those applied transversely to the entire territory and likely to be regionalized implied to take account of both components. Since we need annual data, we had to aggregate the original information by operational program at NUT's III level and rearrange that. Sometimes a specific year gathers expenditure of more than one CSF. Yet the information of DGDR referring cohesion fund also had different organization. Then, concerning the CSF's the unit of reference for evaluating the expenditure was primarily collected by Fund, once there are different institutions managing each of them, and after that organized by year. It's worth to say that values for the third CSF were not definitive values.

The information provided by DGAL referred to the expenditure with acquisition of capital assets[27]. Given the different accounting standard in respect the projects promoted by municipalities it had to be corrected in order to avoid overvaluation of the total amount. In fact, the national counterpart of public expenditure realized by municipalities[28] was already considered by DGDR in ERDF and Cohesion Fund. Then, the parcel of local financing was subtracted from the annual expenditure got through DGDR, once it already was considered in public expenditure realized by municipalities with capital assets. To avoid duplication in the component of community financing through a specific fund, we discounted the municipalities' expenditure from the Community Fund amount they have received each year, since Fund' expenditure already was in DGDR information.

Moreover, the expenditure was expressed in national currency at the time of its realization. Therefore from 1988 to 1998, the values were converted through the annual average national currency units per ECU. Thereafter, the fixed rate of national currency was used. Furthermore the series concerning the public investment were adjusted to constant prices at 1995, using the General Fixed Capital Formation deflator.

The official source to the others variables used in this study (gross value added[29], population and employment) is the National Statistic Institute (INE). Gross Value Added, from national accounts, was referred to different year base and was harmonized using implicit real annual changes and also adjusted at constant prices of 1995.

The data base that we constructed resorts to a panel data of 30 regions and 18 annual observations over the period 1988-2005, thus combining cross section with time-series data.

[27] Capital Expenditure (Class 07) - Acquisition of Capital Assets in according the New Classifier of Economic Expenditures of Local Government. It was made available by DGAL - General Directorate of Local Administration. These values were corrected from the part already included in funds in order to avoid duplication.

[28] Community Fund + National Counterpart (municipal financing + funding from other sources, State Budget and Own Revenues).

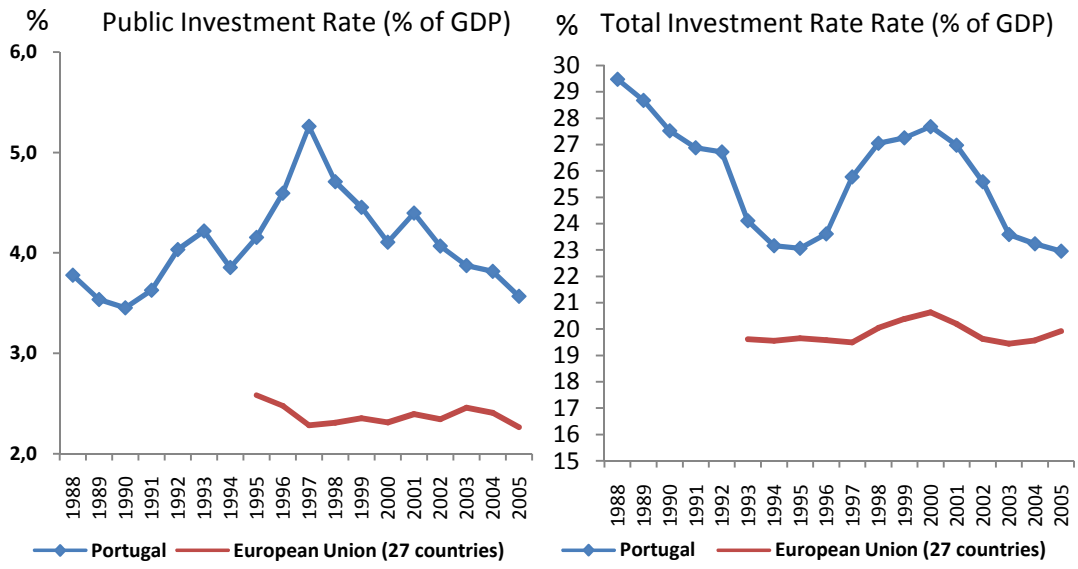
[29] GVA was used, given the lack of information to the regional NUTS III level for domestic product. The latter is obtained applying a single net taxes coefficient.

For the regressions that we will realize the data will be aggregated into three separated periods: 1988-1995, 1996-2000 and 2001-2005 using only 90 of 510 observations. This will help to distinguish between medium-term versus the annual (short run) and to allow the necessary lags for public investment to have effects on GVA and therefore on the growth rate of the period afterwards.

### 3.3. Stylized Facts: Regional Allocation of Public Investment and its Evolution (1988-2005)

In the context already presented, how relevant is the total investment in general and public investment in particular, in Portuguese economy?

***Figure 2 - Public and Total Investment Rate (% of GDP)***




Source: AMECO

During the period we analyze, 1988-2005, the Portuguese investment rate as percentage of GDP (25.4%)[30] was higher than that of European Union average (19.8%) and United States (18.4%). Among European Union Countries, this is similar to the one of Spain (25%) but superior to those of Ireland (21.5%) and Greece (21.2%), the others

[30] Source: AMECO

European Cohesion Countries. Few of new European members' investment rates overcome the Portuguese one (Estonia, Slovakia, and Czech Republic) (Figure2).

It's important to notice that the general government gross fixed capital formation means nearly 16.2% of the total gross fixed capital formation and 4% of gross domestic product compared with 12.6% and 2.5% respectively to the European Union average. The share of public investment in GDP has declined since the end of nineties both in the European Union and Portugal. Is also worth noting that general government gross fixed capital formation in our country grew, along the period 1988-2005, at an annual average rate of 7.8%, higher than that of gross domestic product of 2.9%. This evolution occurred also in European Union but with a narrow differential (3.3% and 2.4%, respectively[31]).

Although the size of public investment is small when compared with the total investment, we want to understand whether its amount, evolution and regional allocation may shed some light on knowing if it contributes to a regional asymmetries reduction and convergence to the national average.

The data set of public investment we have constructed represents almost 85% of the general gross fixed capital formation in the period. It's worth to say that some public investment expenditures at country level are not likely to affect to a specific region although they have an indirect effect on that.

We will now begin to focus the analysis on the data that will help us to answer the two questions of this thesis.

Since 1988 to 2005, public investment expenditure reached an annual average value of M€ 3816 at 1995' constant prices. If we consider the following three periods of analysis - 1988-1995, 1996-2000 and 2001-2006, - its annual average value grew 56.3% and 42.7% on second and third period relative to the previous period.

[31] 1995-2005

Considering the per capita public investment annual average at constant prices it was around €375 along 1988 – 2005. Its growth rate was respectively 54.5% and 38.6% in the second and third periods under review, compared to the previous period.

The regional distribution of the public investment expenditure annual average along the three periods considered reveals an increase of its coefficient of variation, measured at constant prices, from the first (1988-1995) to the second period (1996-2000), showing greater dispersion in the latter. From the second to the third period (2001-2005) the coefficient has reduced significantly, meaning a less asymmetric regional allocation. The coefficient of variation assumed respectively the value of 1,029, 1,215 and 0,736 in those periods.

Table 1: Public Investment' Coefficient of Dispersion among Portuguese Regions (NUTSIII)

| 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1,068** | **0,929** | **0,827** | **1,051** | **0,950** | **1,197** | **1,100** | **1,171** | **1,549** | **1,310** | **1,144** | **1,098** | **1,078** | **0,726** | **0,834** | **0,906** | **0,664** | **0,708** |

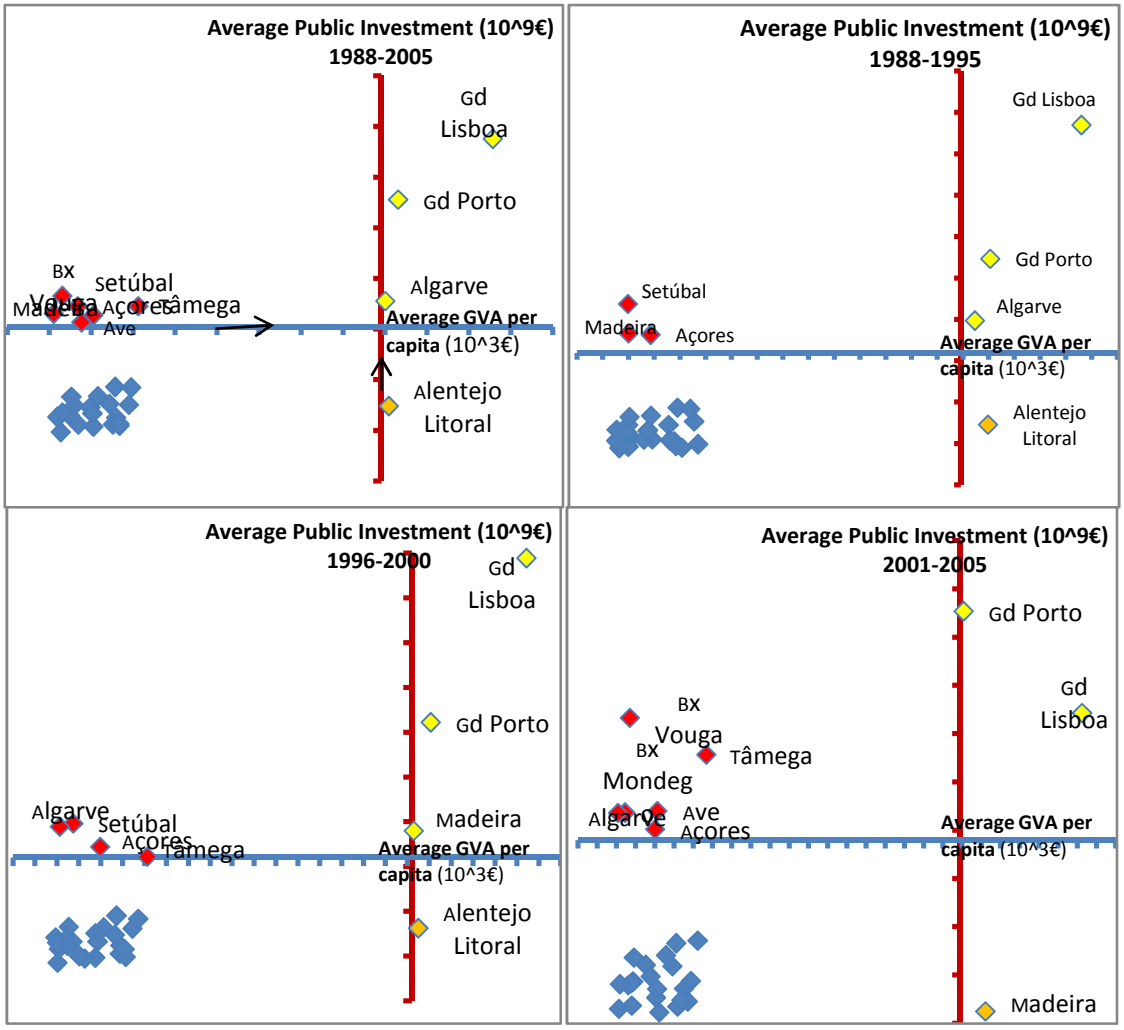
However, taking the calculation to NUTS III public investment expenditure per capita the coefficient of variation, also at constant prices, decreases from the first to the second period, just from 0,581 to 0,466, and worsens the last of the periods considered to 0,507, which however means a less asymmetric regional distribution than in the first period.

Relating the regional allocation of public investment between 1988 and 2005, to the level of the regions gross value added per capita, it reveals that 20 of the 26 regions with GVA per capita below the national average, they were allocated with public investment as a lower proportion than the average.

Of total 30 NUTS III regions, 21 benefited, in the period under analysis, of public investment below the national average. However, the 4[32] regions with a per capita GVA above the average, account for about 50% of the GVA and absorb 33% of public investment. Most notable are, Grande Lisboa and Grande Porto that received together more than a quarter of public investment (Figure 3).

[32] Grande Lisboa, Grande Porto, Algarve and Alentejo Litoral

*Figure 3 - GVA per capita and Public Investment Allocation*




In the third period Madeira and Setubal' Peninsula began receiving public investment below the national average while the latter continues registering a GVA per capita below the average.

This pattern remained similar over the three periods considered although some regions have changed their relative position and the regional average of both variables - public investment and per capita GVA - has progressively increased throughout the three periods.

Baixo Vouga, Ave and Baixo Mondego, although remaining with per capita GVA under the average, managed leaving the group receiving less public investment to the group

which receives more than the average in the last period, suggesting a spatial distribution of public investment a bit less asymmetric. Also, the two macro-regions of Grande Lisboa and Grande Porto, that strengthened their uptake of public investment from the first to the second period, reduced significantly their conjoint participation in the regional distribution (20%) due the lower share of the first one.

We can summary this first set of empirical evidence by saying that the allocation of public investment across regions did not have as a first objective the decrease of regional difference when this are measured by GVA per capita differentials.

What the effect of this allocation on the growth and on the convergence of those regions is the aim of next section.

### 3.4. Testing for σ-convergence (sigma-convergence)

Using the expression for σ-convergence presented before[33] the figure below shows a decrease in the coefficient of variation of product per capita, meaning that regional disparities have decreased from 1988 to 2005.

Meanwhile, breaking the analysis into the periods associated with the execution of each of the Community Support Framework, a different path is observed.

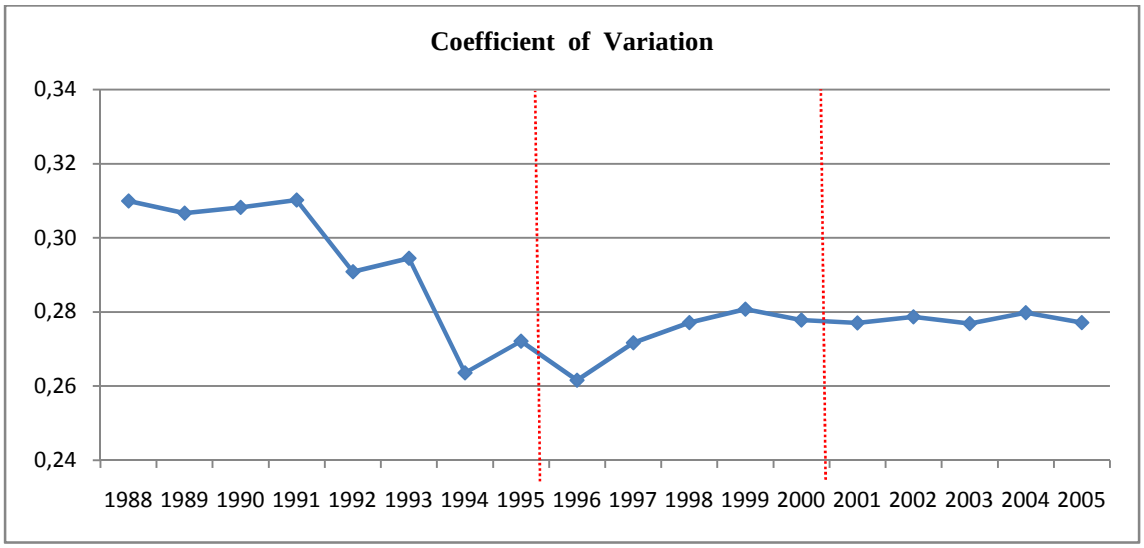
Along the first period, 1988-1995, there has been some fluctuation in the dispersion of per capita product across regions, with the coefficient of variation decreasing, namely across the second half of this period, revealing an improvement in convergence.

Conversely, along the second period, 1996-2000, although the coefficient of variation remained at a lower level than that of the overall previous period, this path was changed into dispersion. Notice that this period (1996-2000) coincide largely with the CSF II running period, where the allocation of expenditures did not address regional convergence as a main goal. It worth to say that the economic growth rate had just

[33] The formula used is given by: $\frac{\sqrt{\frac{1}{N}*\sum_{i=1}^{N}(y_i-\bar{y})^2}}{\bar{y}}$

accelerated during this second period, 4%, what compares with 2.5% in the first period.

***Figure 4 – GVA per Capita, σ-convergence (1988-2005)***




Finally, in the third time-span, 2001-2005, the σ-convergence hasn't changed significantly, remaining almost constant.

# 4. ECONOMETRIC FRAMEWORK

## 4.1. Econometric Specification

We now want to disentangle the conditional effect, $\beta_1$, from the effect of public investment on growth, $\beta_2$.

Resorting from the equation (1) and following Rodriguez-Pose, et al., (2012), the following specification was used:

$$\frac{1}{T} ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \propto_i + \beta_1 ln(y_{i,0}) + \beta_2 PubInv_{it} + \beta_3 (WPubInv_t)_i + \beta_4 X_{it} + \mu_{it} \qquad (2)$$

The dependent variable, $\frac{1}{T}\ln\left(\frac{y_{i,T}}{y_{i,0}}\right)$ is the average growth rate of GVA per capita, and $i$ refers the region. $0$, $t\ and\ T$, refer, respectively, the initial year, the period $t$ and its length (Table 2.1). $\mu_{it}$ is the error term.

Explanatory variables are: $y_{i,0}$, the GVA per capita value at the initial period, $PubInv_{it}$, that stands for public investment in region $i$ in period $t$.

As we have said we want also to test whether the public investment done in neighbors regions to the one that we are analyzing has effects on growth. With this aim we are going to introduce $(WPubInv_t)_i$ that represents the public investment in regions' $i$ neighbors where W is a binary matrix of contiguity assuming the value 1 if the region is a neighbor of $i$ and 0 otherwise. Notice that with $(WPubInv_t)_i$ specification, one looks for capturing the regional spatial dependence implied by a relation of territorial contiguity between a region and its neighbors with a common frontier.

We know that growth differential across regions can be influenced by other variables. We are going to choose those for which we have available data and which a *priori* could be more relevant. Then, $X_{it}$, from equation (2) allows for encompassing others control variables such as population density (*PopDensity*) or GVA sectoral share (*ShareAgric, ShareIndustry and ShareServices*). Coefficients β capture, respectively, $\beta_1$, the effect of the initial per capita product on the average growth rate that allows for the analysis of the convergence process, $\beta_2$, the direct effect of public investment on the average growth rate and $\beta_3$, the spillover effect implied by the public investment of neighboring regions on region $i$. We expect going to get $\beta_1$ negative, meaning the convergence across Portuguese NUTS III regions. On the contrary, $\beta_2$ could be positive, considering the large amount channeled to the regions or negative if we take account of the allocation presented. $\beta_3$ can reach both signals whether public investment in neighboring regions has an extension effect on region $i$ in order to exploit synergies or there is such competition for public investment location determined by economic or political lobbies. This is also related to the type of investment. The construction of a highway naturally picks up various regions in

the same draft public investment while building a hospital in a region can derail the construction of another in contiguous region.

Variables $PubInv_{it}$ and $WPubInv_t$ will be treated as averages of the period, generating respectively $AvPubInv_{it}$ and $AvWPubInv_t$.

### 4.2. The Panel Approach and Methodology

In the present work we deal with panel data focusing on several techniques. The use of panel data enables us to account for individual heterogeneity. According to Marques (2002), panel data has got a number of advantages over the cross sectional approach. A Panel contains repeated observations in different moments for each of the units providing a larger number of observations. It allows for controlling unobserved heterogeneity at the unit level and omitted variables persistently along the time, thus, improving efficiency in estimators. Also implies greater data variability and less colinearity between variables. Moreover, panel data facilitate the analysis of the dynamic of the adjustment.

First of all we will use the Ordinary Least Square (OLS) assuming homogeneity between regions NUTS III, that is, a common intercept and slope. Hence, we assume that the errors are not correlated with the regressors and OLS method is appropriate producing consistent and efficient estimators. Yet, this is a restrictive hypothesis, once the units distinguish by regional specific characteristics. Moreover, the observations are not independent and may be correlated with explanatory variables. In that case, OLS does not provide consistent estimators and the Fixed Effects model (hereafter FE) will be the more adequate to model the regional heterogeneity. Then we consider different intercepts to capture regional own specificities which remain invariant along the time. Using FE, we assume that specificities within each region may affect the estimator or the variables result, that is, we assume that there is correlation between unit's error term and explaining variables. With fixed effects one can remove the time-invariants characteristics and get the estimator net effect, once the fixed ones are being controlled. Another way to deal with FE is encompassing least square dummy regional variables that capture the individual effects of each region, controlling for the

unobserved heterogeneity (LSDV). Both ways will give the same results for explaining variables.

Another model would be considering that the variation across regions is random and uncorrelated with the independent variables in the model. This is the Random Effects Model (RE). In that case, coefficients encompasses both the within and between unit effects, that is, the average effect of explaining variable on the dependent variable when the first one changes across time and between regions by one unit .

The Hausman test will be applied to analyze the appropriateness of FE or RE and the Modified Wald test to control for the heteroskedasticity. We also tested for the need of using time-fixed effects or not. The test F also was applied to test the hypothesis of a common constant (homogeneity) or heteroskedasticity. Always it was appropriate the variance covariance estimator option, (vce (robust)), to get robust standard errors for the parameter estimates was used (Bertrand, et al., 2004).

To identify the spatial autocorrelation concerning the variable PubInv the Moran's I[34] statistic was applied.

# 5. EMPIRICAL RESULTS

## 5.1. Absolute β-convergence

The main question under absolute β-convergence analysis is to know if the regions tend to converge towards the same GVA per capita independently of initial conditions (Barro and Sala-i-Martin, 1991 e 1992). In neoclassical growth model the per capita growth rate tends to be inversely related to the level of output per person (Solow, 1956). Then, in this section we analyze this type of convergence based on what the data show.

[34] $I = \frac{n}{\sum\sum w_{ij}} \frac{\sum\sum w_{ij}(y_i-\bar{y})(y_j-\bar{y})}{\sum(y_j-\bar{y})^2}$, where n is the number of spatial units indexed by ***i*** and ***j***; Y is the variable of interest; $\bar{y}$ is the mean of y; and $w_{ij}$ is an element of a matrix of spatial weights.

$$\frac{1}{T} ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \propto + \beta ln(y_{i,0}) \quad (3)$$

The estimation of the equation (3) by OLS shows that there had been absolute β-convergence of the Portuguese Regions from 1988 to 2005, once the β coefficient of convergence comes negative and significant (-0.0222). It shows that as $y_{i,0}$ varies, the per capita GVA average growth rate decreases, that is, a change of 1% in the initial level implies a convergence of 2,2%. These results enable us to confirm that absolute convergence is present in the sample of Portuguese regions for the period (Figure 2.2).

The F-statistic shows that the regression is jointly significant at 1% significance level. However is to underline that the coefficient of regression ($R^2$) is too low revealing a low explanatory power. Thus, it is possible that the regional dynamic be affected by others factors beyond those captured by initial per capita GVA. Should be noted that the $\beta$ coefficient corresponds to an estimated rate of convergence, $\lambda$, of only 0.12% on average, per year, exhibiting a low convergence path.

In order to identify if the error term is not correlated with the estimator, allowing for random effects, we applied the Hausman test. Its result indicates that the fixed effects model is preferred.

Table 3.10 presents the estimation results using fixed effects. There is the same evidence, but the net effect of the initial per capita GVA over the per capita average growth rate is more strong, the coefficient coming (-0.0592) and the rhythm of convergence higher. Table 3.2 considers also time fixed effects to the regression, which was justified by testing the hypothesis of periods' coefficients being zero[35]. It results in a higher effect on the per capita GVA growth average rate (-0.1280).

It's interesting to analyze whether it happened in all the periods considered. It was done in Tables 3.3-3.5 and (also Table 2.6) by including a dummy variable taking the value 1 for the period into analysis and 0 otherwise. Therefore, breaking the analysis by periods, only for the first period, there is evidence of absolute β-convergence of

[35] Join test to analyze if dummies for all periods are equal to zero (Testparm)

Portuguese Regions. For the others periods the results do not allow any conclusion, once they are not statistically significant. However, the first CSF run at that time, was the lowest of the three CSF's representing 28.4% of the total expenditure along the period 1988-2005. It is likely that this first CSF has had a greater effect in regions further away from some economic dynamism than in those who already were on track, thus contributing positively to convergence.

These results of existence of absolute convergence can be extended by questioning whether the speed of convergence is changing when controlled by other variables. One of those variables could be public investment in the region (or nearby) which is other issue treated in this work.

### 5.2. Conditional β-convergence

With the aim of understanding how the process of β-convergence changes when conditioned by others variables we are going to estimate the following equation:

$$\frac{1}{T} ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \propto_i + \beta_1 ln(y_{i,0}) + \beta_2 AvPubInv_{it}, \qquad (4)$$

where *AvPubInv* is the average of public investment expenditure during the spam period, that is, the per capita GVA average growth rate is going to be conditioned by that variable.

The analysis of conditional β-convergence, first, was made applying the OLS method. Using Tables 2.3 and 3.6 we can see that the coefficient $\beta_1$ associated to the initial value of per capita GVA is quite significant and with negative signal ($\beta_1$ =-0.0218), indicating that conditional β-convergence was verified for the global period (2.2%) and is similar to that of absolute β-convergence.

In Table 3.11 are the results we found for conditional β-convergence when we used fixed effects regression. Again, they indicate that a convergence of 5.7% occurs when the initial level changes of 1%, slightly lower than for absolute β-convergence (5.9%).

Meanwhile, the coefficient $\beta_2$, referring to the variable of interest, the average public investment expenditure reveals no statistical significance explaining the per capita GVA average growth rate, whereas doing an OLS regression (Table 3.6) or controlling regional fixed effects as can be seen using the table 3.11. In order to capture the elasticity of growth rate with respect to the dynamic of average public investment, we also explored the alternative of considering in these regressions the logarithm of *AvPubInv* but, yet, this variable is not statistically significant (Table 3.7 and 3.12).

Our results go in a different direction from those of Rodriguez-Pose, et al., (2012) in their study for Greek regions where they found a positive effect of public investment on regional per capita growth but rejected the hypothesis of conditional β-convergence for the period 1978-2007.

To improve the estimation of conditional β-convergence we extended the equation (4) including others variables that may explain the long run steady state (Table 2.2).

One of these was the population density to take account of the dimension of each region influencing its economic growth. More populated regions may increase the domestic demand taking advantage of economies of scale and boosting economic growth. In fact, population is relevant to understand the economic dynamic and this subject has been debated since the Malthus's theories. Amartya Sen (Sen, 1999), for instance, says that, "nowadays, the largest growth per capita took place in more densely populated areas". However, this is a complex relation and also may have negative impacts on growth, depending on the characteristics of population, the technologies and the productivity, among others factors.

On Table 3.8, we can see the following results: population density variable reveals itself significant although negligible for per capita GVA growth rate, but it does not help analyzing the effect of public investment on that growth rate, once this latter variable comes without statistical significance. When using fixed effects model (Table 3.13), *PopDensity* presents again a negligible effect but with a negative coefficient,

what means that more populated regions would have lower growth rate. Controlling for this variable the coefficient of convergence is lower.

The breakdown of GVA by economic sector of activity was the other variable we included to reflect structural economic differences, which are theoretically and empirically associated with different levels of development. Yet, when adding the sectorial breakdown of GVA as an explaining variable r, the coefficient of public investment pertains without statistical significance. Surprisingly, when using the OLS method, the industry share reveals an unexpected signal, meaning that an increase in the industry share would imply a lower average growth rate of per capita GVA. The same happens with services share (Table 3.9). It is difficult to find a reasonable explanation for that. When controlling the regional fixed effects, the coefficient associated with share industry becomes positive but the one referred to the services share is not significant (Table 3.14).

As explained before, the geographical closeness of the studied regions leads us to think, as (Rodriguez-Pose, et al., 2012), that the relevant variable to explain growth could be not just public investment in the particular region but also public investment in near region. Therefore we extended the analysis to evaluate if there is spatial autocorrelation concerning the variable *PubInv.* For that a binary neighbors matrix was used and Moran's I statistic was applied. The result implied rejecting the null hypothesis of no spatial autocorrelation. Then, to control the spatial dependence and to assess a spillover effect on the growth rate of a particular region, a new variable, *AvWPubInv,* was added to the equation (4).

$$\frac{1}{T} ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \propto_i + \beta_1 ln\left(y_{i,0}\right) + \beta_2 AvPubInv_{it} + \beta_3 AvWPubInv_{it} \qquad (5)$$

As already said in the econometric specification, *WPubInv* represents the public investment in regions' $i$ neighbors, here expressed in average values.

As can be seen in Tables 2.5 and Table 3.15, we can conclude that considering the average investment in the neighboring regions (*AvWPubInv*) it reflects negatively on growth rate of per capita GVA of region $i$ (OLS), suggesting a kind of crowding out

effect. It is reasonable to think that regions compete for the location of public social facilities and local specific infrastructure that differentiate them from their neighbors. This effect may exceed that of interregional infrastructure serving simultaneously several regions. Furthermore there is a limit for expanding the influence of infrastructure public investment on the private one boosting the economic activity.

To improve the results we repeated the estimations through the Generalized Least Squares (GLS) method. The results maintain the signal of $\beta_1$, revealing that the conditional β-convergence among Portuguese regions is a robust characteristic. However, again, the effect of public investment measured by its average values or by logarithm is not significant.

Table 2.4 compares results of additional regressions to analyze conditional $\beta$ convergence. Again, we extended equation (4) by including together *AvPubInv*, *PopDensity* and *GVA* sectoral breakdown. The fixed effects presence was tested calculating F-Statistic which p-value came significant. Therefore we estimated the model including regional dummies variable (LSDV) and using the fixed effect procedure. The fixed effect by region is significant; the probability above the F value is under 0.05. Also the heterokedasticity was tested through a modified Wald test for groupwise heterokedasticity.

The regressions were repeated including fixed time effects. After the inclusion of time fixed effects the significance of all time coefficients was tested and the null hypothesis of being all zero, rejected. Applying the likelihood ratio test, it points out that the explaining power of our model increases when including them. Therefore, they were considered (LSDVtfe, FEtfe).

Also there is no evidence of random effects when using the test Breush-Pagan lagrange multiplier to compare with a simple OLS regression.

From table 2.3 we can see that the coefficient $\beta_1$ related to the initial per capita period always is negative and significant, evidencing the convergence of Portuguese regions

at level NUTS III. Regarding, the coefficient of public investment is not significant in any of those regressions.

Considering, both, regional and time fixed effects (regressions (3) and (5) on table 2.4), the population' density shows a negative relation with the per capita average growth rate. Controlling for fixed effects, the impact of total GVA' industrial share on the dependent variable is now positive and significant.

Conducting now the analysis of β-convergence conditioned by average public investment and considering the three separated periods we have defined, and using the OLS method, the results show the same path that for absolute β-convergence, that is, only for the first period there is evidence of conditional β-convergence of Portuguese regions, the others not evidencing statistical significance (Table 2.6).

Also when using the Generalized Least Squares (GLS) method in the analysis by separated period, we obtain regional convergence during the first period as with others methods. Furthermore, no statistical significance of public investment explaining the average growth rate of per capita GVA was evident. The negative effect of neighbors' public investment pertains. For the second and third periods the results do not allow for any conclusion about the occurrence of convergence neither about the effect of public investment.

Summing up, the absolute and conditional β-convergence of Portuguese regions occurred for the global period in line with the neoclassical perspective of convergence. Considering three separated period we have found the incidence of β-convergence in the first period (1988-1995). Concerning our variable of interest, the public investment expenditure, whereas the considerable amount of public investment realized during the period under analysis, there is no evidence of a positive effect on the per capita GVA average growth. It seems to support the views of (Boldrin, et al., 2002) (Boldrin, et al., 2003), (Rodríguez-Pose, et al., 2003) or (Gallo, et al., 2007) who share a negative perspective about transferring resources to the lagged European countries to achieve the convergence goal. Moreover, as showed before, the regional allocation of public investment was mostly channeled to the richest regions. Regarding the spillover effect

of public investment in contiguous regions on an individual region, which we have explored through the consideration of the W matrix and including AvWPubInv variable in our regressions, we found a negative impact on per capita growth, contrary to Rodriguez-Pose et al., (2012) for Greek regions.

### 5.3. Sensitivity Analysis

We have explored if our results for β-convergence are sensitive to a change in the periods considered. As already explained, our periods were chosen taking into account the effective expenditure associated with each one of CSF's which do not is coincident with the running time of them.

Then we proceed with a sensitivity analysis to understand how much our results change if we change the periods' delimitation in order to internalize the dynamic of a new CSF with a different structure and rules of implementation.

Then, we redefined the periods making them to coincide with the validity of the CSF's, that is, 1988-1993, 1994-1999 and 2000-2005.

Tables 3.18-3.20 present the results when looking for absolute β-convergence by these new periods. In fact we have got the same outcome, the results showing the same evidence. There was absolute β-convergence of Portuguese regions. Others periods did not have statistic significance.

We also investigated what would be the result considering a single period 1988-2005. As expected, the result goes in same direction also showing the convergence of Portuguese regions. Also, we have explored what would be the changes if we had used all our observations rather aggregating them into ninety. The results do not change significantly neither in sign nor in size [36].

We have repeated the sensitivity analysis when dealing with conditional β-convergence for those new periods. Again, the same conclusion pertains. Considering

[36] The results will be provided upon request

a single period 1988-2005, β-convergence conditioned by average public investment also occurs.

Concerning also the effect of public investment expenditure on the average growth rate of per capita GVA, $\beta_2$, by separated period, again the results are not statistically significant.

### 5.4. Limitations and Further Research

In this study a series for public investment at an aggregated level was used, what did not allow for analyzing the contribution of each type of investment to the economic growth and the to the convergence process. In fact, investing on knowledge accumulation or investing on infrastructure will, in principle, have different consequences on the economic growth. On the other hand, gathering the information from several sources who deal with CSF' expenditure may lack from some harmonization and consistency. Moreover, the proxy used for public investment, may not be the appropriate; although the data covers namely public investment it's likely that encompasses miscellaneous expenditure associated with the implementation of public projects that would be better considered as current expenditure. These are elements to be performed in order to dispose a reliable and detailed database for public investment at a lower spatial level.

In terms of the regression equations specification, other explaining variables could be explored influencing the growth process, such as the schooling level, as a proxy of the human capital, viewed as a guiding force to the convergence process. Another variable to be considered could be one reflecting the influence of political forces in power according regional constituencies. This is also limited by the availability of information at NUTS III level.

# 6. CONCLUSION

In this study we raised the question of understanding if regional convergence of Portuguese Regions NUTS III had occurred as well as how was the contribution of regional public investment allocation to that path. The results provide empirical evidence of regional $\sigma$ and $\beta$-convergence (absolute and conditional) of NUTS III Portuguese regions during the global period 1988-2005 and the first period analyzed, measured by the GVA per capita. This is true in spite of our observation that the allocation of investment across regions may not be connected with an objective of convergence. Meanwhile, the rhythm of convergence seems to be negligible.

We confirmed a spatial dependence of public investment and found a negative impact of regions neighbors' public investment on per capita growth rate of a given region, suggesting some competition for the location of public social facilities and local specific infrastructure.

However, those results don't enable us to evaluate the contribution of public investment policy to that process since the coefficients related with this variable don't have statistical significance, even when extending our analysis controlling for others explaining variables which may influence the long run steady state.

By periods, the results show an improvement of $\sigma$-convergence along the first period to diverge during the second and stabilizing in the third period with a lower coefficient of variation than at beginning. The absolute and conditional $\beta$-convergence results reveals also an improvement in the first period but no conclusion was possible for the others two periods once they do not evidence statistical significance.

Notwithstanding this study has answered our initial questions. The analysis of convergence at the NUTS III territorial level and its relation to the public investment allocation is in fact a contribution of our investigation as well the database constructed.

The results do not support the idea of a public policy allocation guided by the public investment expenditure as a main tool to achieve redistribution of wealth and regional convergence. If we want to defend an economic reasoning behind the allocation (and not a political one) we should have to defend complementarities and higher returns of public investment on richer regions. However, even then is not clear, given our results that that allocation leads to higher growth, compared with the alternative scenario of having not done that type of public investment.

From these results we can't educe clear indications for current policy. The right assessment of the effective regional policy in terms of public investment redistribution and convergence should consider the benefits as well as the opportunity and financing costs.

Policy makers should be provided with rigorous evaluation of regional public policy based on reliable data, suitable indicators and methodology to formulate an efficient policy in this field at national, as well as, European level. Further theoretical developments on factors better explaining regional growth and economic and social cohesion are required, which allows the assessment of the net returns of public investment.

To achieve a country regionally less asymmetric, Portugal should face the new European Union funding cycle (2014-2020) and subsequent public investment projects backed on clear criteria about efficient regional policy instruments integrated in public policies of development.

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# ANNEX 1

## CONVERGENCE HYPOTHESIS IN THE NEO-CLASSICAL MODEL – BRIEF SPECIFICATION

The convergence is one main forecast of the neo-classical growth model of Solow (1956) and Swan (1956). This model assumes a closed economy adjusting instantaneously all the markets, producing a composite good with capital and labor and observing constant returns to scale and decreasing marginal productivity.

The model stems from the dynamic of the capital stock and use a Cobb-Douglas function:

$$Y_t = K_t^{\propto}, A_t, L_t^{1-\propto}, \quad 0 <\propto< 1 \qquad (1)$$

Where $Y_t$ is the output, $K_t$, $L_t$ represent the productive factors capital and labor and $A_t$ stands for the technology. $\propto$ is the elasticity of the output to the capital.

Technology and population growth at rate g and η, respectively and the capital depreciates at δ rate,

$$A_t = A_0 e^{gt}, \quad L_t = L_0 e^{\eta t}$$

One considers a saving rate s as a proportion of the output that will be invested: $s = \frac{S}{Y}$

Dividing equation (1) by $A_t L_t$ will get:

$$\frac{Y_t}{A_t L_t} = \frac{K_t^{\propto}, A_t, L_t^{1-\propto}}{A_t L_t} = \left(\frac{K_t}{L_t}\right)^{\propto} \quad \text{or} \quad \hat{y}_t = \hat{k}_t^{\propto} \qquad (2)$$

$\hat{y}_t$ and $\widehat{k_t}$ being the output and capital in terms of effective work:

$$\hat{y}_t = \frac{Y_t}{A_t L_t} \text{ and } \widehat{k_t} = \frac{K_t}{A_t L_t}$$

The dynamic of k over the time comes from:

$$\dot{\hat{k}} = s\hat{y}_t - (\eta + g + \delta)\widehat{k_t} = s\hat{k}_t^{\propto} - (\eta + g + \delta)\widehat{k_t} \qquad (3)$$

Dividing this last equation by $\hat{k}$ it comes the stock capital growth rate $\gamma_k$ :

$$\gamma_k = \frac{\dot{\hat{k}}}{\hat{k}} = s\frac{\hat{k}_t^{\alpha}}{\hat{k}_t} - (\eta + g + \delta)$$

(4)

Defining the steady state as the moment where $\dot{\hat{k}} = 0$, from equation (3), and after solving in order to $\hat{k}$ it comes:

$$\hat{k}^* = \frac{s}{\eta+g+\delta}^{\frac{1}{1-\alpha}} \quad (5a) \quad \text{and} \quad \hat{y}^* = \frac{s}{\eta+g+\delta}^{\frac{\alpha}{1-\alpha}} \quad (5b)$$

Following, Islam, Nazrul (1995) where the present specification is build on, one can approximates around the steady state. Hence, the rhythm of convergence is given by:

$$\frac{dln\hat{y}_t}{dt} = \lambda[ln(\hat{y}^*) - ln(\hat{y}_t)],\ where\ \lambda = (\eta + g + \delta)(1-\alpha) \quad (6)$$

The solution for this differential equation is:

$$ln\hat{y}_{t_2} = \left(1 - e^{-\lambda T}\right)ln\hat{y}^* + e^{-\lambda T}ln\hat{y}_{t_1} \quad (7)$$

Where $\hat{y}_{t_1}\ and\ \hat{y}_{t_2}$is, respectively, the income per effective work at an initial and final point of time with $\tau = (t_2 - t_1)$.

Subtracting $ln\hat{y}_{t_1}$to both sides of equation (7) it becomes,

$$ln\hat{y}_{t_2} - ln\hat{y}_{t_1} = \left(1 - e^{-\lambda T}\right)\left(ln\hat{y}^* - ln\hat{y}_{t_1}\right) \quad (8)$$

Replacing (5b) into this last equation it yields:

$$ln\hat{y}_{t_2} - ln\hat{y}_{t_1} = \left(1 - e^{-\lambda T}\right)\frac{\alpha}{1-\alpha}ln(s) - \left(1 - e^{-\lambda T}\right)ln(\eta + g + \delta) - \left(1 - e^{-\lambda T}\right)ln\hat{y}_{t_1} \quad (9)$$

On the other hand, taking into account that $A_t = A_0 e^{gt}$ and $\hat{y}_t = \frac{Y_t}{A_t L_t}$ and applying logarithms to this last expression one can get it in terms of income per capita:

$$ln\hat{y}_t = lny_t - lnA_t = lny_t - lnA_0 - \mathrm{g}t \quad (10)$$

Where $A_0$ encompasses not only the technology but endowments, institutions, climate and others elements that may differ across countries.

Replacing in equation (9) the result of equation (10) it comes:

$$\left(lny_{t_2} - lnA_0 - \mathrm{g}t_2\right) - \left(lny_{t_1} - lnA_0 - \mathrm{g}t_1\right) = (1 - e^{-\lambda T})\frac{\alpha}{1-\alpha} ln(s) - (1 - e^{-\lambda T})\frac{\alpha}{1-\alpha} ln(\eta + \mathrm{g} + \delta) - (1 - e^{-\lambda T})(lny_{t_1} - lnA_0 - \mathrm{g}t_1) \quad (11)$$

Again, following Islam, Nazrul (1995), isolating $lny_{t_2}$ on the left-hand side and rearranging the equation will get the usual growth initial level equation:

$$lny_{t_2} = (1 - e^{-\lambda T})\frac{\alpha}{1-\alpha} ln(s) - (1 - e^{-\lambda T})\frac{\alpha}{1-\alpha} ln(\eta + \mathrm{g} + \delta) + e^{-\lambda T} lny_{t_1} + (1 - e^{-\lambda T}) lnA_0 + \mathrm{g}(t_2 - e^{-\lambda T} t_1) \quad (12)$$

Equation (12) is considered a dynamic panel data model, which can be written:

$$y_{it} = \gamma y_{t-1} + \sum_{j=1}^{2} \beta_j x_{it}^j + \mu_i + \eta_t + \upsilon_{it} \quad (13)$$

With, $y_{it} = lny_{t_2}$, $y_{it-1} = lny_{t_1}$, $\gamma = e^{-\lambda T}$, $\beta_1 = (1 - e^{-\lambda T})\frac{\alpha}{1-\alpha}$,
$\beta_2 = -(1 - e^{-\lambda T})\frac{\alpha}{1-\alpha}$, $x_{it}^1 = ln(s)$, $x_{it}^2 = ln(\eta + \mathrm{g} + \delta)$, $\eta_t = \mathrm{g}(t_2 - e^{-\lambda T} t_1)$,
$\mu_i = (1 - e^{-\lambda T}) lnA_0$ , that represents the individual regional effect, constant along the time, and $\upsilon_{it}$ that represents the error term that vary across regions and time periods with mean equal to zero.

Hence the equation (13) represents a dynamic panel data.

Subtracting $y_{t-1}$to both side one gets:

$$lny_{t_2} - lny_{t_1} = e^{-\lambda T} lny_{t-1} - lny_{t_1} + \sum_{j=1}^{2} \beta_j x_{it}^j + \mu_i + \eta_t + \upsilon_{it}$$

$$ln\left(\frac{y_{t_2}}{y_{t_1}}\right) = -lny_{t_1}(1 - e^{-\lambda T}) + a + \upsilon_{it}$$

$$ln\left(\frac{y_{i_T}}{y_{i_0}}\right) = a + blny_{t_0} + v_{it}$$

With, $a = \sum_{j=1}^{2} \beta_j x_{it}^{j} + \mu_i + \eta_t$ e $b = -(1 - e^{-\lambda T})$

as we have presented before when specifying the convergence absolute.

## ANNEX 2: TABLES AND FIGURES

### Figure 2.1 - MAP OF PORTUGUESE REGIONS - NUTS III

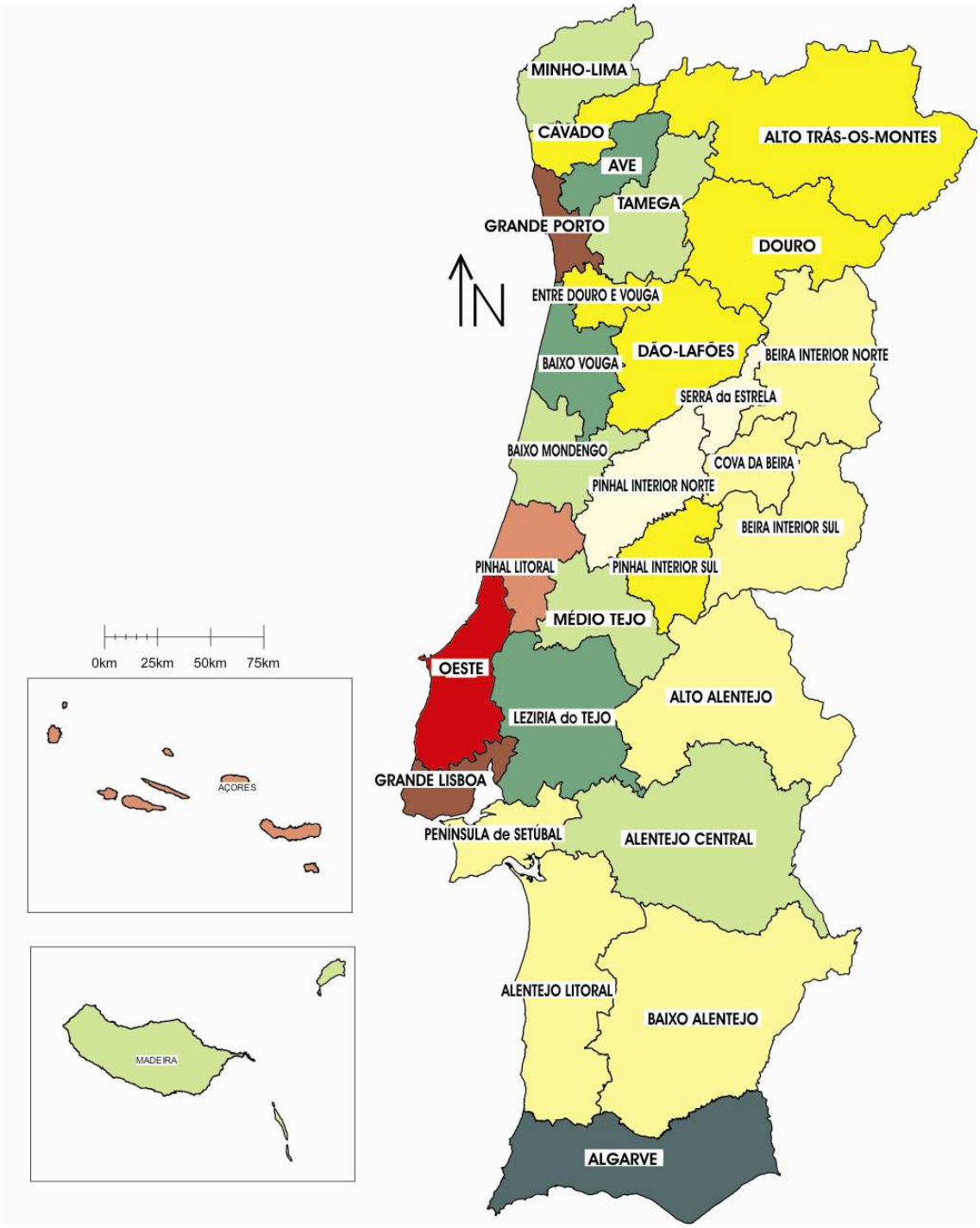

**Figure 2.2 – Absolute β-convergence for Portuguese Regions NUT III (1988-2005)**

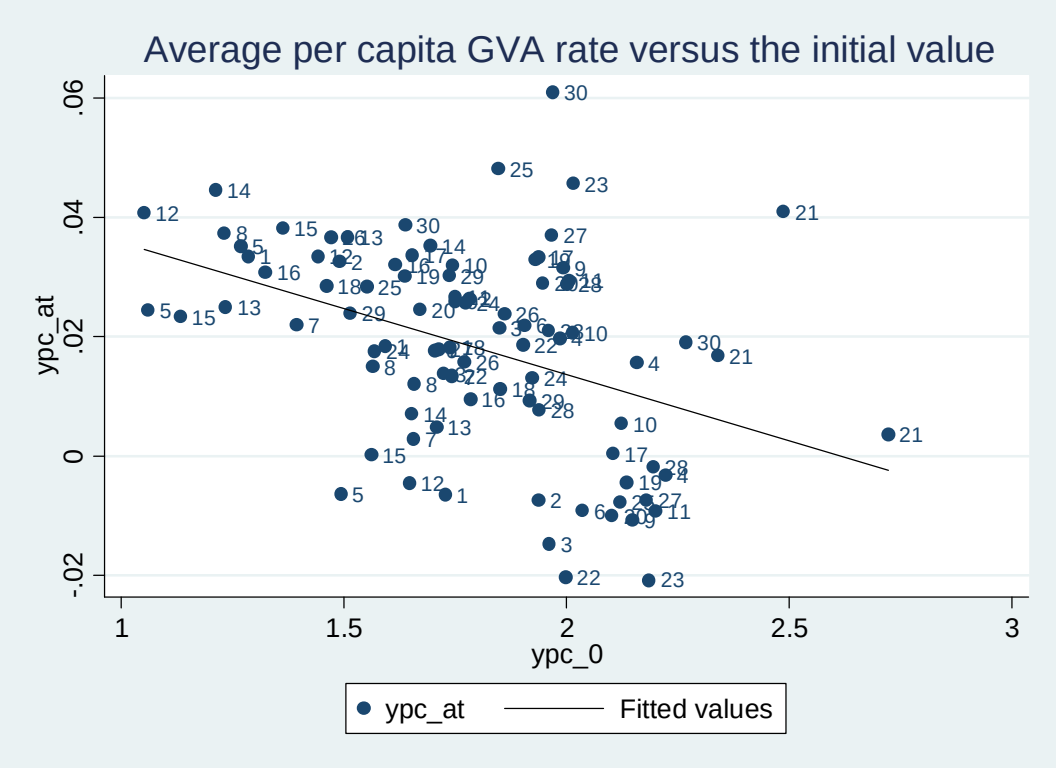

Table 2.1 – Periods of Analysis

| Period of analysis | Initial Moment - $t_o$ | Length of the period - T | Period $t_i$ |
|---|---|---|---|
| 1988-1995 | 1988 | 8 | 1 |
| 1996-2000 | 1996 | 5 | 2 |
| 2000-2005 | 2000 | 5 | 3 |

Table 2.2 – Absolute $\boldsymbol{\beta}$-Convergence

Dependent Variable: Per capita GVA Average Growth Rate

| VARIABLES | (1) OLS | (2) LSDV | (3) FE |
|---|---|---|---|
| ypc_0 | -0.0222*** | -0.0592*** | -0.0592*** |
| | (0.0052) | (0.0069) | (0.0042) |
| Constant | 0.0580*** | 0.1060*** | 0.1240*** |
| | (0.0086) | (0.0113) | (0.0074) |
| Observations | 90 | 90 | 90 |
| R-squared | 0.1697 | 0.5319 | 0.4443 |
| RMSE | 0.0156 | 0.0143 | 0.0117 |
| LogLikelihood | 247.8 | 273.6 | 273.6 |
| F test that all u_i=0 | . | . | . |
| Number of id | | | 30 |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 2.3 – Stata Outputs to Several Regressions

| Dependent Variable: Per Capita GVA Average Growth Rate | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OLS | | | | | | | Fixed Effects | | | | | | | |
| VARIABLES | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| ypc_0 | -0.0222*** | -0.0219*** | -0.0174** | -0.0225*** | -0.0211*** | -0.0195*** | -0.0167** | -0.0592*** | -0.0572*** | -0.0624*** | -0.0546*** | -0.0663*** | -0.0494*** | -0.0601*** |
| | (0.0052) | (0.0067) | (0.0069) | (0.0064) | (0.0065) | (0.0056) | (0.0065) | (0.0042) | (0.0079) | (0.0187) | (0.0062) | (0.0169) | (0.0079) | (0.0185) |
| AvPubInv | | -0.0000 | | -0.0000 | | 0.0000 | | | -0.0000 | | 0.0000 | 0.0000 | 0.0000 | |
| | | (0.0000) | | (0.0000) | | (0.0000) | | | (0.0000) | | (0.0000) | (0.0000) | (0.0000) | |
| lnAvPubInv | | | -0.0028 | | | | -0.0012 | | | 0.0016 | | | | 0.0056 |
| | | | (0.0028) | | | | (0.0030) | | | (0.0085) | | | | (0.0111) |
| Pop Density | | | | 0.0000** | 0.0000*** | | | | | | -0.0003*** | -0.0001 | | |
| | | | | (0.0000) | (0.0000) | | | | | | (0.0001) | (0.0001) | | |
| Share Industry | | | | | -0.0006** | | | | | | | 0.0032*** | | |
| | | | | | (0.0003) | | | | | | | (0.0008) | | |
| Share Services | | | | | -0.0005 | | | | | | | 0.0011 | | |
| | | | | | (0.0004) | | | | | | | (0.0009) | | |
| AvWPubInv | | | | | | -0.0000*** | | | | | | | -0.0000 | |
| | | | | | | (0.0000) | | | | | | | (0.0000) | |
| lnAvWPubInv | | | | | | | -0.0064** | | | | | | | -0.0063 |
| | | | | | | | (0.0027) | | | | | | | (0.0073) |
| Constant | 0.0580*** | 0.0576*** | 0.0809*** | 0.0592*** | 0.1044*** | 0.0607*** | 0.1433*** | 0.1240*** | 0.1216*** | 0.1120* | 0.1742*** | -0.0147 | 0.1114*** | 0.1433** |
| | (0.0086) | (0.0098) | (0.0257) | (0.0093) | (0.0287) | (0.0086) | (0.0267) | (0.0074) | (0.0108) | (0.0648) | (0.0187) | (0.0664) | (0.0113) | (0.0603) |
| Observations | 90 | 90 | 90 | 90 | 90 | 90 | 84 | 90 | 90 | 90 | 90 | 90 | 90 | 84 |
| R-squared | 0.1697 | 0.1697 | 0.1816 | 0.1950 | 0.2344 | 0.3196 | 0.2853 | 0.4443 | 0.4456 | 0.4450 | 0.4713 | 0.5904 | 0.4613 | 0.4738 |
| RMSE | 0.0156 | 0.0157 | 0.0156 | 0.0155 | 0.0153 | 0.0143 | 0.0144 | 0.0117 | 0.0118 | 0.0118 | 0.0116 | 0.0103 | 0.0117 | 0.0116 |
| LogLikelihood | 247.8 | 247.8 | 248.4 | 249.2 | 251.4 | 256.7 | 239.0 | 273.6 | 273.7 | 273.6 | 275.8 | 287.3 | 275.0 | 256.9 |
| F test that all u_i=0 | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| Number of id | | | | | | | | 30 | 30 | 30 | 30 | 30 | 30 | 28 |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 2.4 - Conditional $\boldsymbol{\beta}$-Convergence - Comparison

| Dependent Variable –per capita GVA Average Growth Rate | | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| VARIABLES | OLS | LSDV | LSDVtfe | FE | FEtfe | RE |
| ypc_0 | -0.0211*** | -0.0663*** | -0.1465*** | -0.0663*** | -0.1465*** | -0.0211*** |
| | (0.0065) | (0.0201) | (0.0295) | (0.0169) | (0.0165) | (0.0039) |
| AvPubInv | -0.0000 | 0.0000 | -0.0000 | 0.0000 | -0.0000 | -0.0000 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Pop Density | 0.0000*** | -0.0001 | -0.0004** | -0.0001 | -0.0004** | 0.0000*** |
| | (0.0000) | (0.0001) | (0.0001) | (0.0001) | (0.0002) | (0.0000) |
| Share Agric | | -0.0011 | 0.0004 | | | 0.0005 |
| | | (0.0011) | (0.0010) | | | (0.0004) |
| Share Industry | -0.0006** | 0.0021*** | 0.0012** | 0.0032*** | 0.0008 | -0.0001 |
| | (0.0003) | (0.0005) | (0.0005) | (0.0008) | (0.0009) | (0.0002) |
| Share Services | -0.0005 | | | 0.0011 | -0.0004 | |
| | (0.0004) | | | (0.0009) | (0.0009) | |
| Constant | 0.1044*** | 0.0580 | 0.2109*** | -0.0147 | 0.3395*** | 0.0562*** |
| | (0.0287) | (0.0424) | (0.0472) | (0.0664) | (0.0923) | (0.0113) |
| Observations | 90 | 90 | 90 | 90 | 90 | 90 |
| R-squared | 0.2344 | 0.6550 | 0.8156 | 0.5904 | 0.7811 | |
| RMSE | 0.0153 | 0.0127 | 0.00947 | 0.0103 | 0.00761 | 0.0153 |
| LogLikelihood | 251.4 | 287.3 | 315.5 | 287.3 | 315.5 | . |
| F test that all u_i=0 | . | . | . | . | . | . |
| Number of id | | | | 30 | 30 | 30 |
| F | 6.97 | 7.70 | 12.58 | | | |
| Rho | | | | 0.9283 | 0.9967 | |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 2.5 - Conditional $\boldsymbol{\beta}$-Convergence - Comparison (including AvWPubInv)

| Dependent Variable (ypc_at) –per capita GVA Average Growth Rate | | | | | | |
|---|---|---|---|---|---|---|
| VARIABLES | (1) OLS | (2) LSDV | (3) LSDVtfe | (4) FE | (5) FEtfe | (6) RE |
| ypc_0 | -0.0184*** | -0.0640*** | -0.1469*** | -0.0640*** | -0.1469*** | -0.0184*** |
| | (0.0063) | (0.0203) | (0.0293) | (0.0171) | (0.0159) | (0.0038) |
| AvPubInv | 0.0000 | 0.0000 | -0.0000 | 0.0000 | -0.0000 | 0.0000 |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| AvWPubInv | -0.0000*** | -0.0000 | -0.0000 | -0.0000 | -0.0000 | -0.0000*** |
| | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |
| Pop Density | 0.0000 | -0.0000 | -0.0004** | -0.0000 | -0.0004** | 0.0000 |
| | (0.0000) | (0.0001) | (0.0001) | (0.0001) | (0.0001) | (0.0000) |
| Share Agric | | -0.0013 | 0.0004 | | | 0.0005 |
| | | (0.0010) | (0.0010) | | | (0.0003) |
| Share Industry | -0.0003 | 0.0020*** | 0.0012** | 0.0033*** | 0.0008 | 0.0002 |
| | (0.0003) | (0.0006) | (0.0005) | (0.0008) | (0.0008) | (0.0002) |
| Share Services | -0.0005 | | | 0.0013 | -0.0004 | |
| | (0.0004) | | | (0.0008) | (0.0009) | |
| Constant | 0.0970*** | 0.0531 | 0.2092*** | -0.0360 | 0.3378*** | 0.0469*** |
| | (0.0257) | (0.0427) | (0.0469) | (0.0610) | (0.0887) | (0.0105) |
| Observations | 90 | 90 | 90 | 90 | 90 | 90 |
| R-squared | 0.3511 | 0.6593 | 0.8174 | 0.5956 | 0.7832 | |
| RMSE | 0.0142 | 0.0128 | 0.00952 | 0.0103 | 0.00762 | 0.0142 |
| LogLikelihood | 258.9 | 287.9 | 315.9 | 287.9 | 315.9 | . |
| F test that all u_i=0 | . | . | . | . | . | . |
| Number of id | | | | 30 | 30 | 30 |
| F | 11.26 | 7.91 | 16.11 | | | |
| Rho | | | | 0.8773 | 0.9965 | |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 2.6 - $\boldsymbol{\beta}$ - Convergence - Analysis by Period

| | Absolute β-Converence | | | Conditional β-Converence) | | |
|---|---|---|---|---|---|---|
| VARIABLES | 1988-1995 | 1996-2000 | 2000-2005 | 1988-1995 | 1996-2000 | 2001-2005 |
| ypc_0 | -0.0165*** | -0.0036 | -0.0093 | -0.0150** | -0.0048 | -0.0078 |
| | (0.0046) | (0.0108) | (0.0106) | (0.0069) | (0.0116) | (0.0103) |
| AvPubInv | | | | -0.0000 | 0.0000 | -0.0000 |
| | | | | (0.0000) | (0.0000) | (0.0000) |
| Pop Density | | | | 0.0000 | -0.0000** | 0.0000 |
| | | | | (0.0000) | (0.0000) | (0.0000) |
| Share Agric | | | | | | 0.0023* |
| | | | | | | (0.0012) |
| Share Industry | | | | -0.0003 | 0.0011** | -0.0001 |
| | | | | (0.0003) | (0.0005) | (0.0004) |
| Share Services | | | | -0.0002 | 0.0016* | |
| | | | | (0.0004) | (0.0008) | |
| Constant | 0.0521*** | 0.0327 | 0.0211 | 0.0695** | -0.0973 | 0.0081 |
| | (0.0074) | (0.0199) | (0.0210) | (0.0318) | (0.0651) | (0.0303) |
| Annual Convergence Speed λ | 0,2075 | | | 0,003 | | |
| Observations | 30 | 30 | 30 | 30 | 30 | 30 |
| R-squared | 0.3102 | 0.0040 | 0.0271 | 0.3589 | 0.2930 | 0.3802 |
| RMSE | 0.00742 | 0.0150 | 0.0147 | 0.00772 | 0.0137 | 0.0127 |
| LogLikelihood | 105.6 | 84.45 | 85.07 | 106.7 | 89.59 | 91.84 |

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

## Annex 3: STATA RESULTS

**Table 3.1** - Stata Output for per capita GVA average growth rate regressed on its initial level

Absolute β-convergence - (OLS)

```
. xi:reg ypc_at ypc_0, vce(robust)

Linear regression                               Number of obs =      90
                                                F(  1,    88) =   18.31
                                                Prob > F      =  0.0000
                                                R-squared     =  0.1697
                                                Root MSE      =   .0156
```

| ypc_at | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_0 | -.0221765 | .0051831 | -4.28 | 0.000 | -.0324767 | -.0118762 |
| _cons | .0579596 | .0086459 | 6.70 | 0.000 | .0407776 | .0751416 |

**Table 3.2** - Comparison of Regressions (OLS, LSDV, Fixed Effects and Random Effects)

```
. estimates table OLS LSDV FE LSDVtfe RE, star stats(N)
```

| Variable | OLS | LSDV | FE | LSDVtfe | RE |
|---|---|---|---|---|---|
| ypc_0 | -.02217647*** | -.05917595*** | -.05917595*** | -.1280092*** | -.02217647*** |
| id | | | | | |
| 2 | | .01394424 | | .02776162** | |
| 3 | | .01003593 | | .03132625* | |
| 4 | | .03030414*** | | .07066795** | |
| 5 | | -.0128611 | | -.03084787** | |
| 6 | | .01553514 | | .03938533** | |
| 7 | | .00125451 | | .0055596 | |
| 8 | | .00336348 | | -.0001061 | |
| 9 | | .02580395* | | .05528*** | |
| 10 | | .02937979*** | | .05864655*** | |
| 11 | | .0271158** | | .05808865*** | |
| 12 | | -.001086 | | -.01177574 | |
| 13 | | .00400037 | | .00043952 | |
| 14 | | .01292219 | | .01183674 | |
| 15 | | -.00538092 | | -.01797443* | |
| 16 | | .01129371 | | .01395659** | |
| 17 | | .02880108** | | .05378041*** | |
| 18 | | .01295579* | | .0231345** | |
| 19 | | .02606481** | | .05122234*** | |
| 20 | | .02137407* | | .04694578*** | |
| 21 | | .06341495*** | | .13097762*** | |
| 22 | | .00925272 | | .03305482* | |
| 23 | | .03086802 | | .06654352** | |
| 24 | | .01665612 | | .03175386*** | |
| 25 | | .02579812 | | .04673653** | |
| 26 | | .02003537** | | .03139551** | |
| 27 | | .02543765 | | .05418823** | |
| 28 | | .02658445* | | .06165127*** | |
| 29 | | .01708943* | | .02998368*** | |
| 30 | | .04949906** | | .07862704*** | |
| Period | | | | | |
| 2000 | | | | .03241107*** | |
| 2005 | | | | .02814349 | |
| _cons | .05795963*** | .10598294*** | .12396484*** | .19150037*** | .05795963*** |
| N | 90 | 90 | 90 | 90 | 90 |

legend: * p<0.05; ** p<0.01; *** p<0.001

```
r; t=0.11 17:21:30
```

**Table 3.3-3.5** - Stata Output for analysis of Absolute β-convergence by period

```
. reg ypc_at ypc_0 if pt1==1, vce(robust)

Linear regression                                      Number of obs =      30
                                                       F(  1,    28) =   13.11
                                                       Prob > F      =  0.0011
                                                       R-squared     =  0.3102
                                                       Root MSE      =  .00742

------------------------------------------------------------------------------
             |               Robust
      ypc_at |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ypc_0 |  -.0164987   .0045567    -3.62   0.001    -.0258328   -.0071647
       _cons |   .0521038   .0074508     6.99   0.000     .0368414    .0673662
------------------------------------------------------------------------------

r; t=0.02 16:53:16

.
end of do-file

r; t=0.02 16:53:16
. do "C:\Temp\STD00000000.tmp"

. reg ypc_at ypc_0 if pt2==1, vce(robust)

Linear regression                                      Number of obs =      30
                                                       F(  1,    28) =    0.08
                                                       Prob > F      =  0.7770
                                                       R-squared     =  0.0040
                                                       Root MSE      =  .01501

------------------------------------------------------------------------------
             |               Robust
      ypc_at |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ypc_0 |   -.003627    .012681    -0.29   0.777    -.0296027    .0223488
       _cons |   .0327412   .0218669     1.50   0.146     -.012051    .0775334
------------------------------------------------------------------------------

r; t=0.02 16:54:39

.
end of do-file

r; t=0.02 16:54:39
. do "C:\Temp\STD00000000.tmp"

. reg ypc_at ypc_0 if pt3==1, vce(robust)

Linear regression                                      Number of obs =      30
                                                       F(  1,    28) =    1.26
                                                       Prob > F      =  0.2715
                                                       R-squared     =  0.0271
                                                       Root MSE      =  .01469

------------------------------------------------------------------------------
             |               Robust
      ypc_at |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ypc_0 |  -.0093244   .0083133    -1.12   0.272    -.0263535    .0077047
       _cons |   .0211134    .016876     1.25   0.221    -.0134556    .0556823
------------------------------------------------------------------------------

r; t=0.02 16:55:07
```

**Table 3.6** - Stata Output for analysis of Conditional β-convergence - Per capita GVA average growth rate regressed on its initial level and average Public Investment *(AvPubInv)* - (OLS)

```
. xi:reg ypc_at ypc_0 AvPubInv, vce(robust)

Linear regression                               Number of obs =      90
                                                F(  2,    87) =    9.69
                                                Prob > F      =  0.0002
                                                R-squared     =  0.1697
                                                Root MSE      =  .01569

------------------------------------------------------------------------------
             |               Robust
      ypc_at |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ypc_0 |  -.0218541   .0067196    -3.25   0.002      -.03521   -.0084982
    AvPubInv |  -1.35e-09   2.50e-08    -0.05   0.957    -5.11e-08    4.84e-08
       _cons |   .0575522   .0098373     5.85   0.000     .0379995     .077105
------------------------------------------------------------------------------
```

**Table 3.7** - Stata Output for analysis of Conditional β-convergence - Per capita GVA average growth rate regressed on its initial level and Public Investment *(lnAvPubInv)* - (OLS)

```
. xi:reg ypc_at ypc_0 lnAvPubInv, vce(robust)

Linear regression                               Number of obs =      90
                                                F(  2,    87) =    8.79
                                                Prob > F      =  0.0003
                                                R-squared     =  0.1816
                                                Root MSE      =  .01557

------------------------------------------------------------------------------
             |               Robust
      ypc_at |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ypc_0 |  -.0174048   .0069212    -2.51   0.014    -.0311615   -.0036482
   lnAvPubInv|  -.0027653   .0028346    -0.98   0.332    -.0083994    .0028687
       _cons |   .0808618    .025708     3.15   0.002     .0297643    .1319592
------------------------------------------------------------------------------
r; t=0.02 17:29:22
```

**Table 3.8** - Stata Output for analysis of Conditional β-convergence - Per capita GVA average growth rate regressed on its initial level, Public Investment and Density of Population - (OLS)

```
. xi:reg ypc_at ypc_0 AvPubInv PopDensity, vce(robust)

Linear regression                                      Number of obs =      90
                                                       F(  3,    86) =    7.58
                                                       Prob > F      =  0.0001
                                                       R-squared     =  0.1950
                                                       Root MSE      =  .01553
```

| ypc_at | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_0 | -.0225247 | .0064059 | -3.52 | 0.001 | -.0352592 | -.0097901 |
| AvPubInv | -2.62e-08 | 3.24e-08 | -0.81 | 0.421 | -9.07e-08 | 3.82e-08 |
| PopDensity | .0000121 | 5.93e-06 | 2.04 | 0.045 | 3.03e-07 | .0000239 |
| _cons | .0592132 | .0092604 | 6.39 | 0.000 | .0408042 | .0776222 |

**Table 3.9** - Stata Output for analysis of Conditional β-convergence - Per capita GVA average growth rate regressed on its initial level, Public Investment, Density of Population and Sectoral Activity Share - (OLS)

```
. xi:reg ypc_at ypc_0 AvPubInv PopDensity ShareAgric ShareIndustry ShareServices, vc
> e(robust)
note: ShareAgric omitted because of collinearity

Linear regression                                      Number of obs =      90
                                                       F(  5,    84) =    6.97
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.2344
                                                       Root MSE      =  .01533
```

| ypc_at | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_0 | -.0211309 | .0065436 | -3.23 | 0.002 | -.0341436 | -.0081182 |
| AvPubInv | -2.87e-08 | 3.27e-08 | -0.88 | 0.384 | -9.38e-08 | 3.64e-08 |
| PopDensity | .0000165 | 5.88e-06 | 2.81 | 0.006 | 4.85e-06 | .0000282 |
| ShareAgric | 0 | (omitted) | | | | |
| ShareIndustry | -.0006157 | .0002766 | -2.23 | 0.029 | -.0011657 | -.0000657 |
| ShareServices | -.000482 | .0004086 | -1.18 | 0.242 | -.0012946 | .0003306 |
| _cons | .1044003 | .0287389 | 3.63 | 0.000 | .0472498 | .1615507 |

**Table 3.10** - Stata Output for per capita GVA average growth rate regressed on its initial level Absolute β-convergence - (Fixed Effects)

```
. xtreg ypc_at ypc_0, fe vce(robust)

Fixed-effects (within) regression               Number of obs      =        90
Group variable: id                              Number of groups   =        30

R-sq:  within  = 0.4443                         Obs per group: min =         3
       between = 0.0468                                        avg =       3.0
       overall = 0.1697                                        max =         3

                                                F(1,29)            =    202.04
corr(u_i, Xb)  = -0.7523                        Prob > F           =    0.0000

                                    (Std. Err. adjusted for 30 clusters in id)
```

| ypc_at | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_0 | -.059176 | .0041632 | -14.21 | 0.000 | -.0676907 | -.0506612 |
| _cons | .1239648 | .007427 | 16.69 | 0.000 | .108775 | .1391547 |
| sigma_u | .01572557 | | | | | |
| sigma_e | .01430212 | | | | | |
| rho | .5472981 | (fraction of variance due to u_i) | | | | |

**Table 3.11** - Stata Output for analysis of Conditional β-convergence - Per capita GVA average growth rate regressed on its initial level and average Public Investment *(AvPubInv)* - (Fixed Effects)

```
Fixed-effects (within) regression               Number of obs      =        90
Group variable: id                              Number of groups   =        30

R-sq:  within  = 0.4456                         Obs per group: min =         3
       between = 0.0481                                        avg =       3.0
       overall = 0.1695                                        max =         3

                                                F(2,29)            =    104.74
corr(u_i, Xb)  = -0.7552                        Prob > F           =    0.0000

                                    (Std. Err. adjusted for 30 clusters in id)
------------------------------------------------------------------------------
             |               Robust
      ypc_at |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ypc_0 |  -.0571751   .0079036    -7.23   0.000    -.0733399   -.0410104
    AvPubInv |  -9.64e-09   3.26e-08    -0.30   0.770    -7.63e-08    5.70e-08
       _cons |   .1215959   .0108303    11.23   0.000     .0994454    .1437464
-------------+----------------------------------------------------------------
     sigma_u |   .01583407
     sigma_e |   .01440792
         rho |    .5470534   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

**Table 3.12** - Stata Output for analysis of Conditional β-convergence - Per capita GVA average growth rate regressed on its initial level and Public Investment *(lnPubInv)* - (Fixed Effects)

```
. xtreg ypc_at ypc_0 lnAvPubInv, fe vce(robust)

Fixed-effects (within) regression               Number of obs      =        90
Group variable: id                              Number of groups   =        30

R-sq:  within  = 0.4450                         Obs per group: min =         3
       between = 0.0418                                        avg =       3.0
       overall = 0.1642                                        max =         3

                                                F(2,29)            =     96.37
corr(u_i, Xb)  = -0.7582                        Prob > F           =    0.0000

                                    (Std. Err. adjusted for 30 clusters in id)
------------------------------------------------------------------------------
             |               Robust
      ypc_at |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ypc_0 |     -.0624   .0187417    -3.33   0.002     -.100731   -.0240689
  lnAvPubInv |   .0015554   .0085283     0.18   0.857    -.0158869    .0189977
       _cons |   .1120465   .0647674     1.73   0.094    -.0204177    .2445107
-------------+----------------------------------------------------------------
     sigma_u |   .0160217
     sigma_e |  .01441588
         rho |  .55261134   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

**Table 3.13** - Stata Output for analysis of Conditional β-convergence - Per capita GVA average growth rate regressed on its initial level, Public Investment and Density of Population - (Fixed Effects)

```
. xtreg ypc_at ypc_0 AvPubInv PopDensity, fe vce(robust)/**/

Fixed-effects (within) regression               Number of obs      =        90
Group variable: id                              Number of groups   =        30

R-sq:  within  = 0.4713                         Obs per group: min =         3
       between = 0.0620                                        avg =       3.0
       overall = 0.0264                                        max =         3

                                                F(3,29)            =     85.27
corr(u_i, Xb)  = -0.9928                        Prob > F           =    0.0000

                                    (Std. Err. adjusted for 30 clusters in id)
```

| ypc_at | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_0 | -.0545999 | .0062383 | -8.75 | 0.000 | -.0673588 | -.0418411 |
| AvPubInv | 5.53e-09 | 2.76e-08 | 0.20 | 0.843 | -5.10e-08 | 6.21e-08 |
| PopDensity | -.0002708 | .0000913 | -2.97 | 0.006 | -.0004575 | -.0000841 |
| _cons | .1741515 | .0187121 | 9.31 | 0.000 | .1358811 | .212422 |
| sigma_u | .10470906 | | | | | |
| sigma_e | .01419264 | | | | | |
| rho | .9819594 | (fraction of variance due to u_i) | | | | |

**Table 3.14** - Stata Output for analysis of Conditional β-convergence - Per capita GVA average growth rate regressed on its initial level, Public Investment, Density of Population and Sectoral Activity Share - (Fixed Effects)

```
. xtreg ypc_at ypc_0 AvPubInv PopDensity ShareAgric ShareIndustry ShareServices, fe
> vce(robust)/**/
note: ShareAgric omitted because of collinearity

Fixed-effects (within) regression               Number of obs      =        90
Group variable: id                              Number of groups   =        30

R-sq:  within  = 0.5904                         Obs per group: min =         3
       between = 0.0021                                        avg =       3.0
       overall = 0.0276                                        max =         3

                                                F(5,29)            =     71.88
corr(u_i, Xb)  = -0.9546                        Prob > F           =    0.0000

                                    (Std. Err. adjusted for 30 clusters in id)
```

| ypc_at | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_0 | -.0662636 | .0169069 | -3.92 | 0.000 | -.100842 | -.0316851 |
| AvPubInv | 1.55e-08 | 2.19e-08 | 0.71 | 0.485 | -2.93e-08 | 6.03e-08 |
| PopDensity | -.000081 | .0001077 | -0.75 | 0.458 | -.0003014 | .0001393 |
| ShareAgric | 0 | (omitted) | | | | |
| ShareIndustry | .0032134 | .0007976 | 4.03 | 0.000 | .001582 | .0048447 |
| ShareServices | .0011272 | .00088 | 1.28 | 0.210 | -.0006725 | .0029269 |
| _cons | -.0146603 | .0663869 | -0.22 | 0.827 | -.1504369 | .1211163 |
| sigma_u | .045792 | | | | | |
| sigma_e | .01271782 | | | | | |
| rho | .92838953 | (fraction of variance due to u_i) | | | | |

**Table 3.15** - Stata Output for analysis of Conditional β-convergence - Per capita GVA average growth rate regressed on its initial level, Public Investment, Density of Population, Sectoral Activity Share and AvWPubInv - (OLS)

```
Linear regression                               Number of obs =      90
                                                F(  3,    86) =   14.70
                                                Prob > F      =  0.0000
                                                R-squared     =  0.3196
                                                Root MSE      =  .01428
```

| ypc_at | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_0 | -.0195105 | .0056408 | -3.46 | 0.001 | -.030724 | -.0082971 |
| AvPubInv | 1.09e-08 | 1.90e-08 | 0.57 | 0.569 | -2.69e-08 | 4.86e-08 |
| AvWPubInv | -1.83e-08 | 4.85e-09 | -3.77 | 0.000 | -2.79e-08 | -8.62e-09 |
| _cons | .0606545 | .0085957 | 7.06 | 0.000 | .0435669 | .0777421 |

**Table 3.16** - Stata Output for analysis of Conditional β-convergence - Per capita GVA average growth rate regressed on its initial level, Public Investment, Density of Population, Sectoral Activity Share and AvWPubInv - (Fixed Effects)

```
. xi:xtreg ypc_at ypc_0 AvPubInv AvWPubInv, fe vce(robust)

Fixed-effects (within) regression               Number of obs      =        90
Group variable: id                              Number of groups   =        30

R-sq:  within  = 0.4613                         Obs per group: min =         3
       between = 0.1222                                        avg =       3.0
       overall = 0.2551                                        max =         3

                                                F(3,29)            =     80.58
corr(u_i, Xb)  = -0.6573                        Prob > F           =    0.0000

                                    (Std. Err. adjusted for 30 clusters in id)
```

| ypc_at | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_0 | -.0494153 | .0078916 | -6.26 | 0.000 | -.0655554 | -.0332753 |
| AvPubInv | 1.20e-08 | 3.62e-08 | 0.33 | 0.743 | -6.21e-08 | 8.61e-08 |
| AvWPubInv | -1.31e-08 | 8.49e-09 | -1.55 | 0.133 | -3.05e-08 | 4.23e-09 |
| _cons | .1113938 | .0112825 | 9.87 | 0.000 | .0883186 | .1344691 |
| sigma_u | .01232487 | | | | | |
| sigma_e | .01432678 | | | | | |
| rho | .42530761 | (fraction of variance due to u_i) | | | | |

**Table 3.17** - Stata Output for per capita GVA average growth rate regressed on its initial level Absolute β-convergence considering news periods - (OLS)

```
. reg ypc_aN ypc_ON, vce (robust)

Linear regression                               Number of obs =      90
                                                F(  1,    88) =   20.36
                                                Prob > F      =  0.0000
                                                R-squared     =  0.1650
                                                Root MSE      =  .01291

------------------------------------------------------------------------------
             |               Robust
      ypc_aN |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
      ypc_ON |  -.0183873   .0040752    -4.51   0.000    -.0264859   -.0102887
       _cons |   .0514124    .006791     7.57   0.000     .0379168    .0649081
------------------------------------------------------------------------------

r; t=0.02 19:07:43
```

**Table 3.18-3.20** - Stata Output for analysis of Absolute β-convergence by News Periods

```
. reg ypc_aN ypc_ON if pt4==1, vce(robust)

Linear regression                               Number of obs =      30
                                                F(  1,    28) =    9.50
                                                Prob > F      =  0.0046
                                                R-squared     =  0.2117
                                                Root MSE      =  .00802
```

| ypc_aN | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_ON | -.0137846 | .0044721 | -3.08 | 0.005 | -.0229452 | -.004624 |
| _cons | .0473439 | .0068115 | 6.95 | 0.000 | .0333912 | .0612966 |

Table 3.19

```
. reg ypc_aN ypc_ON if pt5==1, vce(robust)

Linear regression                               Number of obs =      30
                                                F(  1,    28) =    2.28
                                                Prob > F      =  0.1425
                                                R-squared     =  0.0373
                                                Root MSE      =  .01055
```

| ypc_aN | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_ON | .0081887 | .0054259 | 1.51 | 0.142 | -.0029258 | .0193032 |
| _cons | .0118614 | .0096414 | 1.23 | 0.229 | -.007888 | .0316109 |

Table 3.20

```
. reg ypc_aN ypc_ON if pt6==1, vce(robust)

Linear regression                               Number of obs =      30
                                                F(  1,    28) =    1.81
                                                Prob > F      =  0.1890
                                                R-squared     =  0.0490
                                                Root MSE      =  .01101
```

| ypc_aN | Coef. | Robust Std. Err. | t | P>\|t\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| ypc_ON | -.0093438 | .0069411 | -1.35 | 0.189 | -.023562 | .0048743 |
| _cons | .02362 | .0137227 | 1.72 | 0.096 | -.0044896 | .0517295 |

## **Table 3.21** - Statistics Post Estimation Tests

### A) Absolute Convergence

$$\frac{1}{T} ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \propto_i + \beta_1 ln(y_{i,0})$$

#### Test to the inclusion of time fixed effects

```
. testparm i.Period* /*Hº: all time coeficcients are zero */

 ( 1)  2000.Period = 0
 ( 2)  2005.Period = 0

       F(  2,    29) =   53.04
            Prob > F =    0.0000
r; t=0.00 17:03:47
```

#### Test to decide using model with fixed effects or random effects

```
. hausman fe re /*if Prob>chi2 < 0.05, use fixed effects*/
```

| | ——— Coefficients ——— | | | |
|---|---|---|---|---|
| | (b) fe | (B) re | (b-B) Difference | sqrt(diag(V_b-V_B)) S.E. |
| ypc_0 | -.059176 | -.0221765 | -.0369995 | .0068472 |

```
                b = consistent under Ho and Ha; obtained from xtreg
     B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(1) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =       29.20
                Prob>chi2 =      0.0000
```

#### Test for random effects (comparing with OLS)

```
Breusch and Pagan Lagrangian multiplier test for random effects

        ypc_at[id,t] = Xb + u[id] + e[id,t]

        Estimated results:
                          |       Var     sd = sqrt(Var)
                ----------+------------------------------
                   ypc_at |    .0002897         .01702
                        e |    .0002046       .0143021
                        u |          0             0

        Test:   Var(u) = 0
                              chibar2(01) =     0.00
                           Prob > chibar2 =   1.0000
```

**Testing for heteroskedasticity – Modified Wald test-Hº:homoskedasticity**

```
. xttest3 /*Rejecting H:ºThere is heterokedasticty */

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (30)  =   35022.98
Prob>chi2 =      0.0000
```

## B) conditional β-convergence

$$\frac{1}{T} ln\left(\frac{y_{i,T}}{y_{i,0}}\right) = \propto_i + \beta_1 ln(y_{i,0}) + \beta_2 PubInv_{it} + \beta_3 (WPubInv_t)_i + \beta_4 X_{it} + \mu_{it}$$

**Testing for the inclusion of a new variable AvPubInv**

```
. lrtest OLS A /*including ypc_0 and AvPubInv*/

Likelihood-ratio test                                 LR chi2(1)  =      0.01
(Assumption: OLS nested in A)                         Prob > chi2 =    0.9307
```

**Testing for the inclusion of a new variable = PopDensity**

```
. lrtest A Pop

Likelihood-ratio test                                 LR chi2(1)  =      2.78
(Assumption: A nested in Pop)                         Prob > chi2 =    0.0955
r; t=0.02 18:01:15
```

**Testing for the inclusion of a new variable = Sectoral Breakdown**

```
. lrtest Pop Sector

Likelihood-ratio test                                 LR chi2(2)  =      4.52
(Assumption: Pop nested in Sector)                    Prob > chi2 =    0.1046
```

**Testing for the inclusion AvWPubInv**

```
. lrtest A AvW

Likelihood-ratio test                                 LR chi2(1)  =     17.91
(Assumption: A nested in AvW)                         Prob > chi2 =    0.0000
r; t=0.00 18:05:49
```

### Testing for the inclusion of time fixed effects

```
. testparm i.Period /*LSDVtfe*/

 ( 1)  2000.Period = 0
 ( 2)  2005.Period = 0

       F(  2,    53) =   31.93
            Prob > F =    0.0000
```

### Test for the presence of fixed effects

```
. di "Test for the presence of fixed effects; F statistic:   " ((r2lsdv-r2pooled)/(mflsdv-mfpoole
> d))/((1-r2lsdv)/(dflsdv))
Test for the presence of fixed effects; F statistic:   2.3117503
r; t=0.00 22:09:37

. scalar fstatistic=((r2lsdv-r2pooled)/(mflsdv-mfpooled))/((1-r2lsdv)/(dflsdv))
r; t=0.00 22:09:37

. di "Test for the presence of fixed effects; p-valor:   " Ftail(mflsdv-mfpooled,dflsdv,fstatisti
> c)
Test for the presence of fixed effects; p-valor:   .00371483
r; t=0.00 22:09:37
```

### Testing for the inclusion of time fixed effects

```
Likelihood-ratio test                                 LR chi2(2)  =     56.39
(Assumption: LSDV1 nested in LSDVtfe1)                Prob > chi2 =    0.0000
r; t=0.02 22:12:36
```

### Testing for heteroskedasticity – Modified Wald test-Hº:homoskedasticity

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (30)  =    1055.63
Prob>chi2 =      0.0000
```

### Testing for the inclusion of time fixed effects

```
Breusch and Pagan Lagrangian multiplier test for random effects

        ypc_at[id,t] = Xb + u[id] + e[id,t]

        Estimated results:
                    |         Var     sd = sqrt(Var)
            ---------+-----------------------------
              ypc_at |    .0002897         .01702
                   e |    .0001617       .0127178
                   u |           0             0

        Test:   Var(u) = 0
                             chibar2(01) =     0.00
                          Prob > chibar2 =   1.0000
```

### C) including AvWPubInv

#### Test to the inclusion of time fixed effects

```
. testparm i.Period /*LSDVtfe1*/

 ( 1)  2000.Period = 0
 ( 2)  2005.Period = 0

       F(  2,    52) =   22.50
            Prob > F =    0.0000
```

#### Test to decide the inclusion of time fixed effects

```
. lrtest LSDV1 LSDVtfe1

Likelihood-ratio test                                 LR chi2(2)  =     56.12
(Assumption: LSDV1 nested in LSDVtfe1)                Prob > chi2 =    0.0000
r; t=0.02 23:11:39
```

#### Testing for heteroskedasticity – Modified Wald test-Hº:homoskedasticity

```
Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (30)  =    1570.37
Prob>chi2 =      0.0000
```

#### Testing for the inclusion of time fixed effects

```
. lrtest FE1 FEtfe1

Likelihood-ratio test                                 LR chi2(3)  =     57.27
(Assumption: FE1 nested in FEtfe1)                    Prob > chi2 =    0.0000
r; t=0.00 23:14:00
```

#### Test for random effects (comparing with OLS)

```
Breusch and Pagan Lagrangian multiplier test for random effects

        ypc_at[id,t] = Xb + u[id] + e[id,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
                  ypc_at |    .0002897         .01702
                       e |    .0001626       .0127533
                       u |          0             0

        Test:   Var(u) = 0
                                 chibar2(01) =     0.00
                              Prob > chibar2 =   1.0000
```

### Test for the presence of fixed effects

```
. di "Test for the presence of fixed effects; p-valor:   " Ftail(mflsdv-mfpooled,dflsdv,fstatisti
> c)
Test for the presence of fixed effects; p-valor:   .04854133
r; t=0.00 23:16:34


.         di "LM = " ((n*nobsT)/(2*(nobsT-1)))*((sTmres2/sres2-1)^2)
LM = 9476.5128
r; t=0.00 23:17:41

.         scalar LM = ((n*nobsT)/(2*(nobsT-1)))*((sTmres2/sres2-1)^2)
r; t=0.00 23:17:41

. // COMPUTE THE p-value FOR THE TEST
.         di chi2tail(1,LM)
0
```

### Moran's I Statistic to test spatial autocorrelation

**Measures of global spatial autocorrelation**

Weights matrix

```
Name: tentativa
Type: Distance-based (binary)
Distance band: 0.0 < d <= 257000.0
Row-standardized: No
```

Moran's I

| Variables | I | E(I) | sd(I) | z | p-value* |
|---|---|---|---|---|---|
| PubInv | 0.151 | -0.002 | 0.003 | 51.882 | 0.000 |
| WPubInv | 0.390 | -0.002 | 0.003 | 131.920 | 0.000 |